DIMENSIONS NBS

The magazine of the
National Bureau
of Standards
U.S. Department
of Commerce

September 1979

HAPPY ANNIVERSARY, NBS/BOULDER. See page 2.

COMMENT

NBS/BOULDER: TWENTY-FIVE YEARS LATER

September 1979 marks the 25th anniversary of the National Bureau of Standards Laboratories in Boulder, Colorado. It also provides a timely occasion to take stock of what the Laboratories have accomplished for the benefit of mankind and to examine the plans for future contributions.

Those familiar with our history will recall that the Boulder Laboratories were established to meet the needs of the Central Radio Propagation Laboratory (CRPL). The location fulfilled all the special needs and expectations of the site selection committee for the radio research work and proved to be ideal later when the Atomic Energy Commission unexpectedly asked for help in the area of cryogenic measurements.

The Laboratories were dedicated on September 14, 1954, by President Dwight D. Eisenhower to the "welfare of humanity—in America and throughout the world." President Eisenhower spoke of the Laboratories as a new type of frontier in a location that a few decades earlier was the habitat of Indians, buffalo, and later, trappers and miners. In the sense that a frontier is a confrontation with the unknown requiring a mastery of new skills and the gaining of new knowledge, the Boulder Laboratories have indeed been, and continue to be, a major force working on the scientific frontiers.

At the end of the first 10 years, the NBS Technical News Bulletin (September 1964) cited the cryogenic work with parahydrogen, and radio research in the ionosphere as the outstanding achievements of the Laboratories. These scientific contributions of the Boulder Laboratories significantly affected the national and world programs of the day.

In 1962, NBS entered into a cooperative arrangement with the University of Colorado to form the Joint Institute for Laboratory Astrophysics. This program evolved over the years to become an internationally acclaimed activity in atomic and molecular physics, precision metrology, and geophysics.

Despite the transfer of CRPL to the Environmental Science Services Administration in 1965, much of the expertise in radio science remained with NBS and became the basis for some of today's most important programs. These include our world leadership in time and frequency measurement, an understanding of microwaves that permits us to solve measurement-related problems of electromagnetic interference (EMI), and the use of microwaves in nondestructive measurements.

Similarly, cryogenics research at the Boulder Laboratories now has broadened applications in the areas of electromagnetics, where new and faster methods for processing electromagnetic signals in computers, analog-to-digital converters, and other devices are being worked on at low temperatures; in materials science, where new basic information is being developed on elastic-plastic fracture and fatigue; and in thermophysical properties, where molecular theories are now being studied to assist in the prediction of the behavior of fluids of engineering interest.

Whatever the scope of the opportunities or frontiers available to the original staff of the NBS Boulder Laboratories, they are exponentially greater today. Like President Eisenhower in 1964, I am unable to foresee precisely what the accomplishments of the Boulder Laboratories will be in the next 25 years.

However, building on the basic staff competences developed at the Boulder Laboratories in the past 25 years, we can look to growth areas in some of the engineering disciplines. We have excellent competences in electrical, chemical, mechanical, and metallurgical engineering, which should provide the Laboratories with a strong foundation for the new frontiers in engineering measurement that are certain to develop in these disciplines. We are also starting the development of a materials science capability that complements work at NBS Laboratories in Gaithersburg, Maryland. Early in 1979 the Fracture and Deformation Division leadership was transferred from Gaithersburg to Boulder. This transfer will provide a basis for many new activities in the materials sciences. In addition, Boulder will continue to provide strong support for the scientific field of metrology, through its expertise in laser technology and time and frequency measurements.

We look forward to the future. As the technical frontiers of national problems gain increasing importance, we welcome new opportunities to contribute "to the welfare of humanity—in America and throughout the world."

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Contents

ARTICLES

2 **Happy Anniversary, NBS/Boulder**
Celebrating 25 Years of Measurement Research

5 **Radar to the Rescue**
Using Microwaves to Help Preserve an Historic Adobe Church

Special
10 **Accurate Measurement of Ultraviolet Radiation**
Radiometric Calibration Needs of Space Experiments

14 **Liquefied Natural Gas: An Energy Alternative**
Better Measurement Methods for International LNG Trade

INTERFACE

19 **ON LINE WITH INDUSTRY**
Assessing LNG Tank Volume Calibrations

20 **STAFF REPORTS**
First Direct Frequency Measurement of Visible Light Reported
Generic Technique for Accurately Predicting the Thermophysical Properties of Fluid Mixtures
Super Spring

UPDATE

28 **CONFERENCES**
Coal-Based Energy Techniques Conference
Building Rehabilitation Conference
Sixth Temperature Symposium
Conference Calendar

30 **PUBLICATIONS**
New SRM Catalog
"Tip the Scale" Toward Historic Preservation
NBS Publications

32 **NEWS BRIEFS**

COVER STORY:

HAPPY ANNIVERSARY NBS/BOULDER

THIS month DIMENSIONS is largely devoted to the National Bureau of Standards' laboratories in Boulder, Colorado, which are celebrating their silver anniversary. DIMENSIONS takes a pictorial peek back at the laboratory's dedication, brings readers up-to-date with stories and reports concerning present scientific activities, and looks, through a commentary, on future courses for the Boulder laboratories.

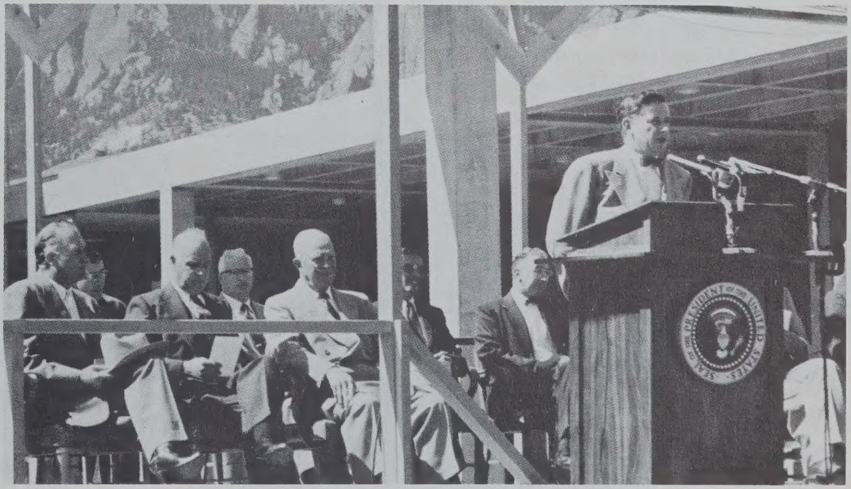
When President Eisenhower delivered his dedicatory address on September 14, 1954, in front of the newly constructed Boulder laboratory building, NBS had two programs operating in Boulder—cryogenic engineering and radio standards and propagation.

In the intervening 25 years, the NBS Boulder laboratories have expanded into other areas of scientific endeavor such as millimeter wave technology, lasers, cryoelectronics, and atomic and molecular physics. NBS retains its cryogenic and radio competences but much of its propagation work was spun off to the National Oceanic and Atmospheric Administration and the National Telecommunications and Information Administration, sister agencies in the Commerce Department that share laboratory space with NBS/Boulder. It should be noted that NBS/Boulder maintains the standard of time and frequency, the only national standard maintained outside of NBS headquarters in Gaithersburg, Md.

In a very real sense, NBS was a pioneer when it moved part of its operations some 2000 miles west in 1954. Until that time, Boulder was best known as the home of the University of Colorado. With NBS' arrival, other scientific organizations—both governmental and private—cast approving glances at Boulder. Today, Boulder is a prosperous city of 80 000 known as a center of academic and scientific excellence.

FPM ☐

Prior to the dedication, Eisenhower was given a special tour of the Radio Building along with (from left to right) Dan Thorton, former Governor of Colorado; Allen V. Astin, former director of NBS; Frederick Brown, former director of the NBS/Boulder Laboratories; and Sinclair Weeks former Secretary of Commerce.



Brown introduces Eisenhower in dedication ceremonies held in September 1954.

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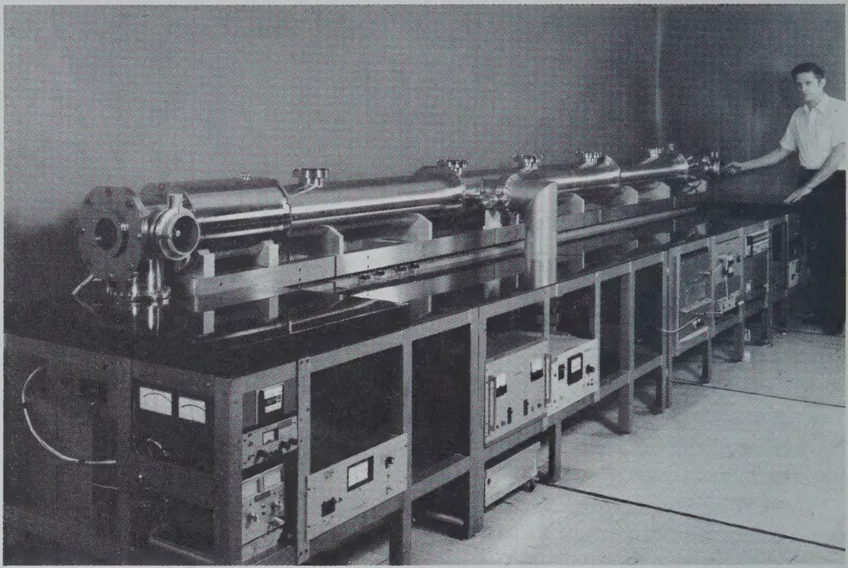
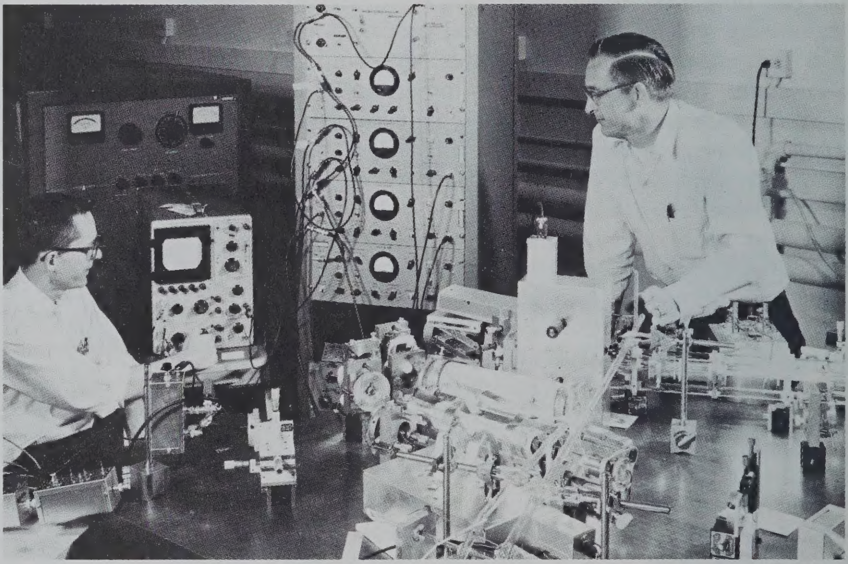
Some Notable Scientific Accomplishments

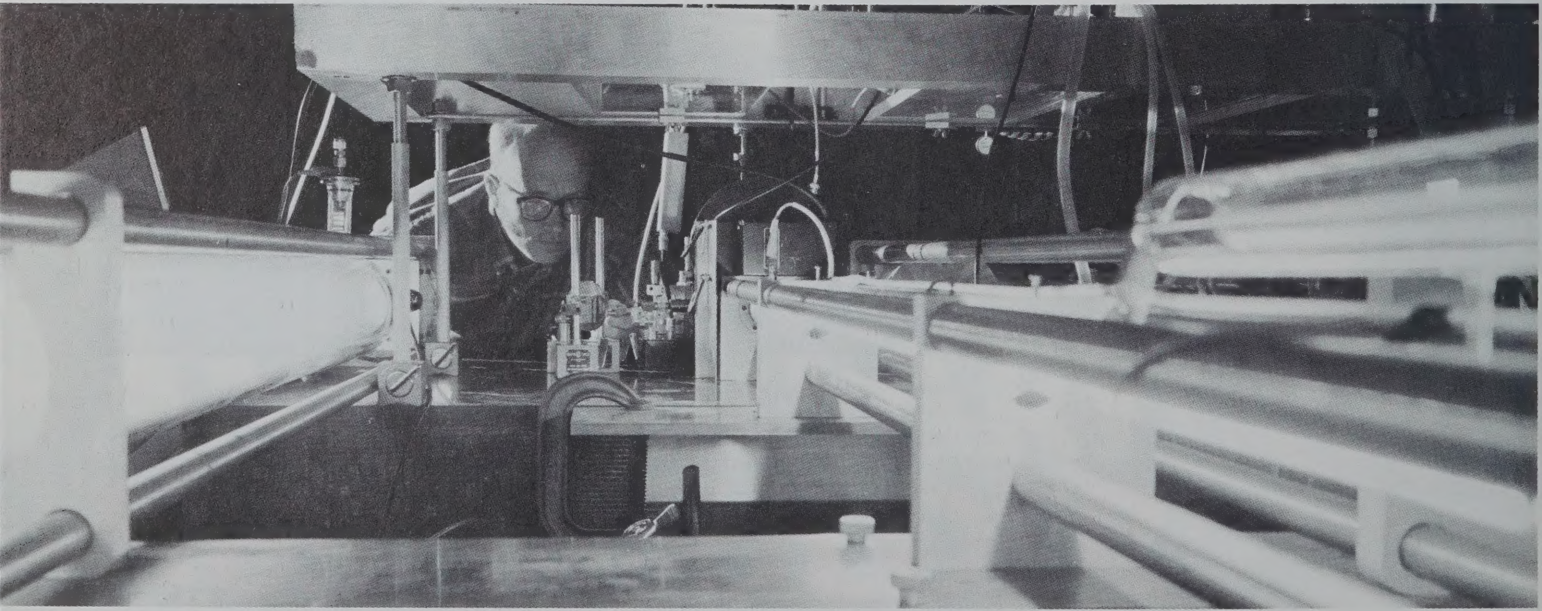


NBS-6, at right, the latest of six generations of NBS primary atomic frequency standards, was completed in 1975. Here NBS physicist, David J. Glaze, makes adjustments on the 6-meter cesium beam tube. NBS-6 achieves an accuracy of better than one part in 10^{13}, and when operated as a clock, can keep time to within 3 millionths of a second per year. It is one part of a complex system of primary and secondary frequency/time standards, computers and instruments which make up the NBS Atomic Frequency and Time System in Boulder.



John L. Hall (left) of the Joint Institute for Laboratory Astrophysics (JILA) and Richard L. Barger of the NBS/Boulder Time & Frequency Division are shown center with the apparatus for their methane stabilized helium-neon laser. In 1969 they revealed a new stabilized laser technique which has greatly aided length measurement via light waves. The technique has also had an important impact on high-accuracy measurements of the speed of light, as well as geophysical measurements.

Kenneth M. Evenson of the NBS/Boulder Time and Frequency Division is shown below peering into the apparatus of an infrared helium-neon laser which, in 1972, was used to make the highest frequency measurement that had ever been made. This experiment helped to make a more accurate the determination of the speed of light and laid the groundwork for linking the international standards of length and time. In 1979, further efforts in cooperation with the Canadian National Research Council achieved the first direct frequency measurement in the visible region of the spectrum. (See page 21.)



Radar to the Rescue

by Frederick P. McGehan

THE United States has a priceless heritage of historic adobe structures in the Southwest that tell us much about the lives and times of early Indian and white settlers .To preserve and maintain this legacy can often be a challenge for government officials entrusted with this responsibility.

Adobe bricks used in these structures were made from mud and straw, put in forms, and allowed to dry and harden beneath the hot sun. They were set in place using mud as mortar. Unfortunately, adobe is subject to erosion by moisture from either ground water or rain.

On more than one occasion, the resources and talents of the National Bureau of Standards have been called upon by the National Park Service

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McGehan is a writer and public information specialist in the NBS Boulder Program Information Office.

turn page

Tumacacori

Anglo-Americans, especially those who have lived most of their lives in the East or Midwest, are often unaware of the culture and tradition brought to the Southwest by Spanish colonists.

Long before the Pilgrims had landed on New England shores, Spanish priests, soldiers, and settlers had populated the Southwest, moving up from Mexico. They introduced farming, founded cities (such as Santa Fe), and brought Christianity to the native Americans.

A typical example of this Spanish presence occurred in the Sonora desert of what is now Southern Arizona and northern Mexico. Spanish Jesuit priests were among the first Europeans to travel by horseback up the Santa Cruz River valley. The river flows between the present cities of Nogales and Tucson, Arizona. There they found a population of about 30 000 Pima Indians who varied in their lifestyles from farmers to nomadic tribesmen.

One of these Jesuits was Father Eusebio Francisco Kino. He first visited the Santa Cruz valley in 1691 and, at the request of residents of the small Pima village of Tumacacori, said Mass under a brush shelter constructed by the Indians. Father Kino stayed in Tumacacori to minister to the Indians, win new converts, and encourage ranching and farming. By 1698, according to Father Kino, Tumacacori had an "earth-roofed house of adobe," fields of wheat, and herds of cattle, sheep, and goats.

After Father Kino died in 1711, there followed a succession of Jesuit missionaries. When the Jesuits were expelled for political reasons from the Spanish colonies in 1767 by King Charles II, they were succeeded by priests of the Franciscan order. The Gray Friars had a hard lot, beset by hostile Apaches, disease, and a dwindling Pima population.

A visitor to Tumacacori in 1797 described the church, built by the Jesuits, as very small and narrow with adobe walls and a flat roof. Within five years Franciscan Father Narciso Guiterrez had begun building a new and much larger church. But the lack of funds and disruptions caused by the Mexican wars for independence delayed the construction.

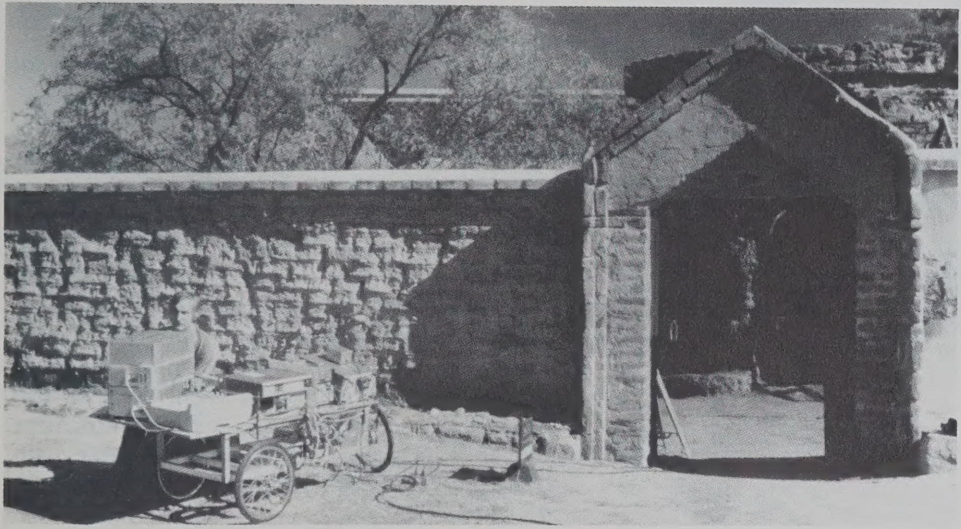
Finally in 1822, two years after Father Gutierrez's death, the new church was put to use. The Tumacacori community, with the large church, Indian pueblo, and surrounding lands, was at its zenith. Curiously, the church building was never fully completed. When the Franciscans were forced to leave Tumacacori in 1828 by a Mexican decree limiting church activity, the construction scaffolding still clung to the bell tower.

For the next 20 years the Pima Indians and a few white settlers struggled to preserve the community. Finally, in 1848, the Apaches conducted a series of brutal raids which drove the last Pimas from the area. The U.S. Army eventually took possession of the Santa Cruz valley and the soldiers along with miners, ranchers, and homesteaders, continued to do battle with the Apaches.

With the settlers at Tumacacori gone, the mission church began to fall into disrepair. It was still used into the 20th century, however, for Holy Week services, and the Pimas continued to bury their dead in the church cemetery. In 1908, President Theodore Roosevelt established the Tumacacori National Monument by Presidential Proclamation. Ten acres were set aside to preserve ". . . one of the oldest mission ruins in the southwest. . . ."

Today, the national monument is run by the National Park Service. It consists of the partially reconstructed church, school, cemetery, walled garden, partially excavated Indian village, and visitor's center.

Under the National Park Service, the condition of the church building has been stabilized rather than restored. Visitors gain a glimpse both of the dedication of the Pima Indians, who labored 20 years on the construction of the mission, and of the ravages resulting from a half-century of attacks by treasure hunters and the weather.



Technician Robert McLaughlin operates FM-CW radar equipment used to locate structural gaps in the cemetery wall at the Tumacacori National Monument.

(NPS) to advance adobe preservation technology and provide standards for preservation techniques.* Most recently, the Park Service asked NBS' Electromagnetic Fields Division in Boulder, Colorado, for help in "seeing through" thick adobe walls with a technique that would avoid destructive penetration of the material.

Specifically, NPS was interested in nondestructive measurement techniques based on microwave technology. For several years, NBS has been using microwave signals at very low power levels to investigate the structure and composition of numerous materials, including snow, soils, rock, and coal.

The Park Service was concerned about the structural integrity of walls at the Tumacacori National Monument, a mission church located in southern Arizona. The church was constructed in the early 1800's by Spanish missionary priests working among the Pima Indians. Abandoned in the mid-nineteenth century, the church structure had deteriorated significantly before it was named a national monument in 1908.

Attempts were made to protect the bricks by covering them with plaster. Often, however, there were gaps between the plaster and the bricks that further promoted deterioration. Park Service preservationists felt they needed more knowledge of the location and extent of these gaps, voids and wet areas if they were to be successful in their efforts.

Until now, the only practical means for finding holes or other faults in an adobe wall was to drill small holes at varying intervals. This method was considered unreliable because drilling could miss small cracks or even large voids that lay parallel to the test hole. Also, the extensive damage to a wall required for a large-scale survey made the technique unacceptable.

In an effort to provide a nondestructive substitute for the drilling method, Donald R. Belsher and Robert H. McLaughlin from the NBS Electromagnetic Fields Division went to Tumacacori at the end of November, 1978. They employed a frequency modulated, continuous wave (FM-CW) radar system. Electromagnetic energy was transmitted into a wall section. At each layer or boundary within the wall, some of the energy was reflected back to a receiving antenna while the remaining energy travelled farther into the materials. By examining the time and amplitude relationships of these reflected signals, the NBS scientists were able to calculate the "relative permittivity" of each area.

Relative permittivity represents a comparison between the energy that can be stored in a volume of material in a given electric field and the energy that can be stored in a vacuum under the same conditions. An adobe brick has about four times the relative permittivity of air; the permittivity of water is almost eighty times as great as that of air. The key to using this technique for examining adobe brick is in being able to correlate the differences in the electrical properties of the wall (primarily the relative permittivity) with the changes in physical structure. In making such a correlation, scientists in the Electromagnetic Fields Division draw on extensive

turn page

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* *See DIMENSIONS, March 1977, "A Legacy Built of Adobe: Preserve With Care."*

Shown at right is a cross section of the Tumacacori cemetery wall (top) and a graph of the radar response when examining different sections. The solid line depicts the radar response when aimed at a solid section of the wall, while the dashed line shows the response when aimed at a section with a niche of the inner wall missing. Note how the "bumps" in the graph represent discontinuities in the wall.

Photo taken of the Tumacacori Mission on July 4, 1889 showing a front view of the bell tower (right) and the entry to the sanctuary. Because the belfry lacked a dome, rain rotted out the floor and leaked down to weaken the ceiling in the room below.

This photo, circa 1913, depicts the results of abuse from the environment. By this time, the roof of the sanctuary and the choir loft had collapsed completely.

A later view of the mission (date unknown) shows some restoration work completed. Reconstructing the roof and ceiling of the sanctuary was the first step in this process. Pine beams were brought 25 miles from the Santa Rita Mountains for the ceiling, just as the Indian builders of the mission had done more than a century earlier.

experience in measuring the electromagnetic properties of materials.

Belsher and McLaughlin made microwave surveys of the nave and sanctuary walls and of a wall surrounding the cemetery at Tumacacori. The radar system was able to detect the mud mortar joints within the walls and also, at one spot in the cemetery wall, a niche approximately 30 centimeters by 40 centimeters. "It is probable, based on these results, that an FM-CW system can be very useful for void detection," Belsher wrote in his report.

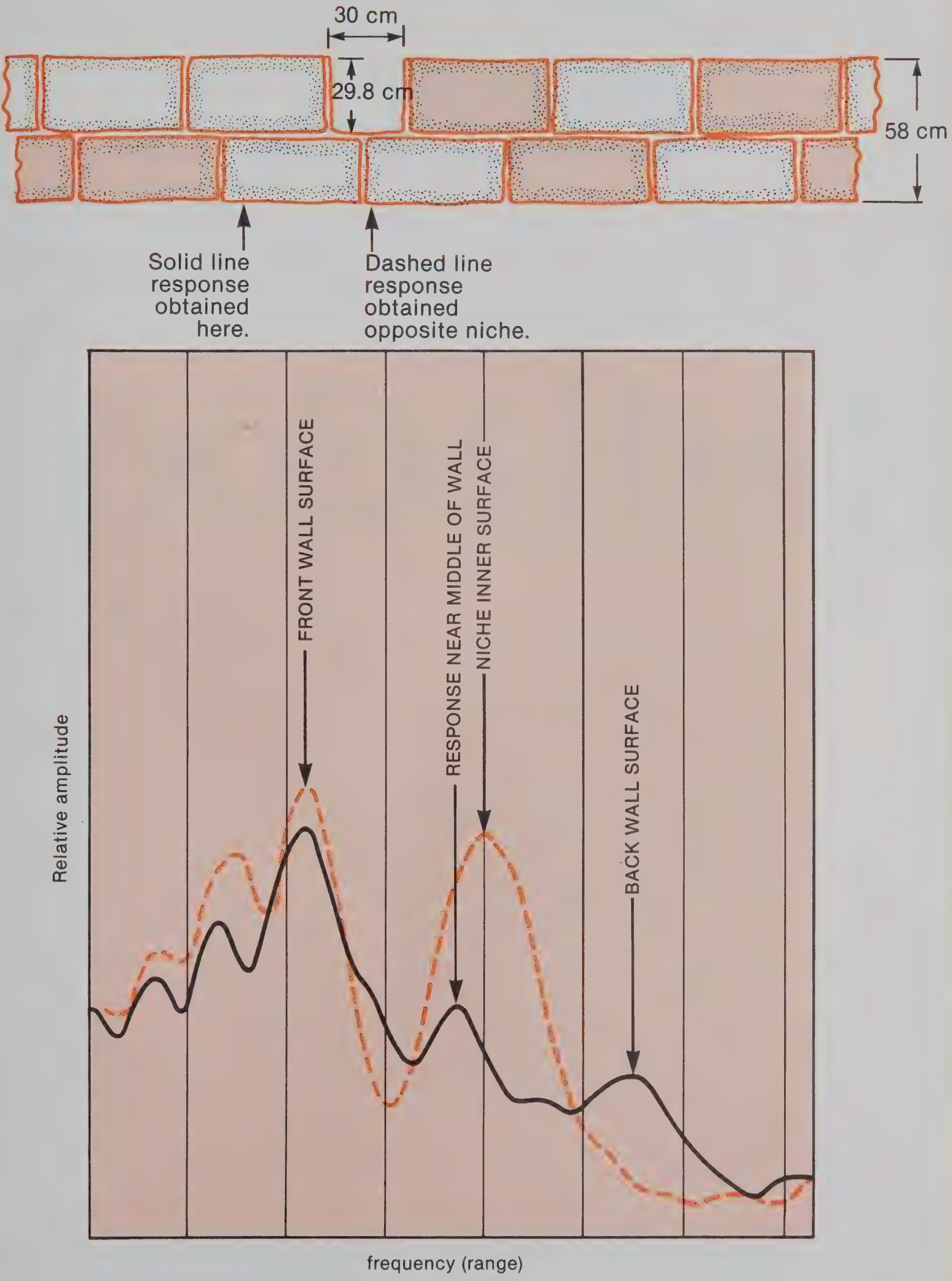
Most important, perhaps, was the finding that amounts and distribution of water within the walls could be measured in relative terms. Belsher also noted that any sudden change in moisture content within an adobe wall should be detectable with the microwave system, although none was found at the Tumacacori site.

"The value of an FM-CW radar system for evaluating adobe walls seems established," Belsher concluded, noting that such a system can be operated "at a relatively low cost and in less time than present techniques." One decided advantage of the radar system is that it can rapidly scan large sections of adobe wall, avoiding the hit-or-miss aspects of manual drilling.

Anthony Crosby, an historical architect with the Park Service's Denver Service Center and supervisor of the Tumacacori preservation project, termed the NBS results "extremely important in the whole area of building preservation." To his knowledge, it was the first time that microwave techniques had been used to study the structural integrity of historic building materials.

The next step, Crosby said, is to build an adobe test wall so that researchers can evaluate the accuracy of the microwave equipment and provide basic information as a guide for future field investigations. Holes would be left in the test wall and, with a known amount of moisture in the bricks, various wall coverings would be placed over the adobe at known intervals. The wall would then be probed by the radar system for voids and other faults.

Both Crosby and Belsher foresee other uses for FM-CW radar systems, such as surveying historical buildings, probing Civil War battlefield sites, and exploring ancient ruins such as a Mayan village buried under 2 to 9 meters of volcanic ash in the jungles of El Salvador in Central America. To inform other investigators of this new technique, Belsher will deliver a paper describing the NBS work before the Association of Preservation Technology meeting in Denver this month. ☐


30 cm
29.8 cm
58 cm
Solid line response obtained here.
Dashed line response obtained opposite niche.
Relative amplitude
FRONT WALL SURFACE
RESPONSE NEAR MIDDLE OF WALL
NICHE INNER SURFACE
BACK WALL SURFACE
frequency (range)

SPECIAL

ACCURATE MEASUREMENT OF Ultraviolet Radiation

by Jeffrey L. Linsky

THE ability to make accurate measurements of ultraviolet radiation is essential in many areas of research, including astronomy. Unlike their experimental colleagues in the laboratory, astronomers can gain direct knowledge of many of the phenomena they wish to study—such as temperatures, densities, and winds of celestial bodies—only by detecting and analyzing the radiation emitted by distant objects. Much of the emission "useful" to these researchers is in the far ultraviolet region of the electromagnetic spectrum. To detect and analyze such radiation requires that experiments be conducted in space, above the earth's absorbing atmosphere.

As in many other fields, the National Bureau of Standards is a technical resource for the scientific community involved in this area of endeavor. NBS is responsible for developing and maintaining radiation standards for all wavelengths used in science and industry. As part of the effort to fulfill this responsibility, NBS conducts a program in ultraviolet standards to develop accurate laboratory sources, detectors, and measurement techniques. Essential to the success of the program is the transfer of NBS expertise to the user community.

Last March, the Bureau sponsored a conference called Workshop on Vacuum Ultraviolet Calibration of Space Experiments. This meeting, fifth in a series of workshops, represents one means by which NBS gathers and disseminates information in an area of growing importance.*

New Research Goal

In attendance with NBS physicists were scientists and engineers from industry, universities, and other government laboratories who are building or operating ultraviolet space experiments on existing NASA satellites or who will be concerned with experiments on future NASA satellites and shuttle missions. Throughout the conference, participants reiterated the need to work toward a new research objective, that of determining average solar ultraviolet irradiance from the whole solar disk to an accuracy of a few percent. This goal complements the more general aim of determining the average solar constant (total irradiance from the sun) with a precision of 0.1 percent.

These objectives have grown out of recent technical concerns such as long-term, possibly interrelated changes in both the chemistry of the earth's atmosphere and our terrestrial climate—changes that may to an extent be induced by manmade effects. Solar radiation is a predominant factor in determining both atmospheric chemistry and climate. Concurrently, the atmosphere screens the planet's surface from much solar radiation, particularly in the ultraviolet region, thus protecting human and other forms of life from hazardous exposure.

Determining the average solar constant within

Linsky is an astrophysicist in the NBS Quantum Physics Division and the Joint Institute for Laboratory Astrophysics (JILA) in Boulder, Colorado. JILA is operated by NBS and the University of Colorado.

* *Similar workshops are held for other areas of ultraviolet measurement.*

0.1 percent and average solar ultraviolet irradiance within a few percent will require many years of continuous effort. Because the energy output of the sun changes over a 22-year cycle, measurements must be carried out for more than 22 years. Measurements of the required accuracy have never before been attempted, but they are in the realm of feasibility. Plans are underway to conduct space experiments that will involve "flyable" transfer standards traceable to a fundamental laboratory source of high precision and stability.

The NBS program in ultraviolet standards should provide much of the expertise that will be required to meet the goals of accuracy. In particular, as participants at the conference pointed out, the NBS storage ring might serve as the single ultimate standard which will make possible the precise measurement of solar irradiance.

NBS SURF-II

This facility, the Synchrotron Ultraviolet Radiation Facility known as NBS SURF-II, was described to conference attendees by Robert Madden, who is the manager of SURF-II.

Madden described the NBS storage ring as an absolute radiometric standard source covering a wavelength range from 4 nanometers (nm) in the ultraviolet to the infrared spectral region. He pointed out that SURF-II is the best characterized synchrotron radiation source in the world today, with a potential accuracy in vacuum ultraviolet radiometry of better than 1 percent. This accuracy is achievable because the geometry of orbit is accurately known, the magnetic fields in the ring have been measured absolutely, and techniques have been developed to count the electrons circulating in the storage ring.

Madden also described a vacuum chamber with internal dimensions of 1.19 x 1.19 x 2.44 meters which is under construction at SURF-II. The chamber will be used to calibrate complete instrument packages for space experiments. It will include a device to rotate and translate the equipment to permit determination of instrumental sensitivity as a function of solid angle and/or displacement over a telescope mirror.

Reports on Recent and Planned Experiments

The second portion of the conference was devoted to a discussion of the stability and precision of the ultraviolet radiometric calibrations performed on recent space experiments. Scientists working on the Atmospheric Explorer, the International Ultraviolet Explorer, Skylab, and on rocket experiments discussed their projects. One conclusion reached at this session was that the present state-of-the-art permits a measurement accuracy of only 12-15 percent at wavelengths longer than 120 nm for stellar and solar measurements in orbit. A need was also expressed for new ideas concerning reliable flyable transfer standards, especially at wavelengths shorter than 160 nm.

The final session included papers on future space missions, including Spacelab, Solar Maximum Mission, and Space Telescope. Guenter Brueckner of the Naval Research Laboratory described his Solar Ultraviolet Spectral Irradiance Monitor, which is designed to measure the variability of solar emission to better than 5 percent over long periods of time. This experiment and one by Paul Simon of the Institut d'Aeronomie Spatiale in Belgium is planned to attain this precision by transporting into space ultraclean redundant spectrographs calibrated at NBS SURF-II and also portable transfer standards such as deuterium lamps.

Current and Future Needs

Determining the average solar ultraviolet irradiance to within only a few percent will require many years of continuous effort.

The ability of these and future experiments to achieve the high precision needed requires the maintenance of one extremely precise absolute calibration facility as a common baseline. Otherwise, scientists will not know whether the small but important changes they may detect in the solar ultraviolet irradiance are instrumental in origin or "real." NBS SURF-II was suggested as the facility to meet this need because it can maintain its stability over a full solar cycle.

Equally important in maintaining precision is the way in which particular experiments are tied to the baseline. This may be accomplished by direct calibration against NBS primary standards, through calibrated secondary standard sources or detectors, or by utilizing other standards laboratories. The reliability of these transfer techniques must also be optimized. Further, one must be able to account for changes in instrument response in space. The space shuttle offers for the first time the opportunity of flying transfer standards as part of the flight package itself. Therefore, scientists also need a better understanding of the long-term aging properties of flyable transfer standards such as deuterium lamps and standard photodiodes. NBS is studying flyable light sources and characterizing photocathode materials in the ultraviolet.*

Experimenters on large astronomical satellites such as Space Telescope face a different calibration problem because their telescopes are too large to fit into calibration facilities. One solution, which was recommended by several speakers at the workshop, would be to establish certain bright stars which are known to have constant ultraviolet fluxes as transfer standards for other, fainter stars and galaxies. But before this can be done, more accurate flux measurements need to be made. So far, only a few stars have been measured to 12-to-15-percent accuracy in the ultraviolet. Almost all of these stars have variable fluxes or are too bright for Space Telescope. However, once a grid of bright star standards has been established, experimenters would be able to calibrate their instruments precisely. ☐

** William Ott and Edward Saloman of NBS reported on these programs.*

Proceedings of the Workshop are available from the author. Write: Jeffrey Linsky, JILA (Division 525), National Bureau of Standards, Boulder, CO 80303, 303/323-3481 (FTS), or 303/492-7838.

turn page

A portion of the National Bureau of Standards program of developing accurate laboratory sources, detectors, and measurement techniques in the ultraviolet is described in the three figures on this page.

Figure 1 shows a comparison of the spectral irradiance (emission from the whole source) of the sun and different sources used in the vacuum ultraviolet radiometry program at NBS. The solar irradiance is given for above and below the terrestrial atmosphere. SURF-II is a laboratory primary standard, while the maxi-arc, mini-arc, and quartz halogen lamps are portable transfer standards. The D_2 lamp and the Xonics Kr_2* lamps are to be flown on Spacelab 1 and 2 for in-flight calibration.

The useful wavelength range of available NBS standard sources is shown in Figure 2. Above the dividing line are laboratory primary standards and below are portable transfer standards.

Shown in Figure 3 is the useful wavelength range of available NBS standard detectors. The double ionization chamber and the electronically calibrated pyroelectric detector (ECPD) are laboratory primary detectors and below the dividing line are portable transfer detectors.

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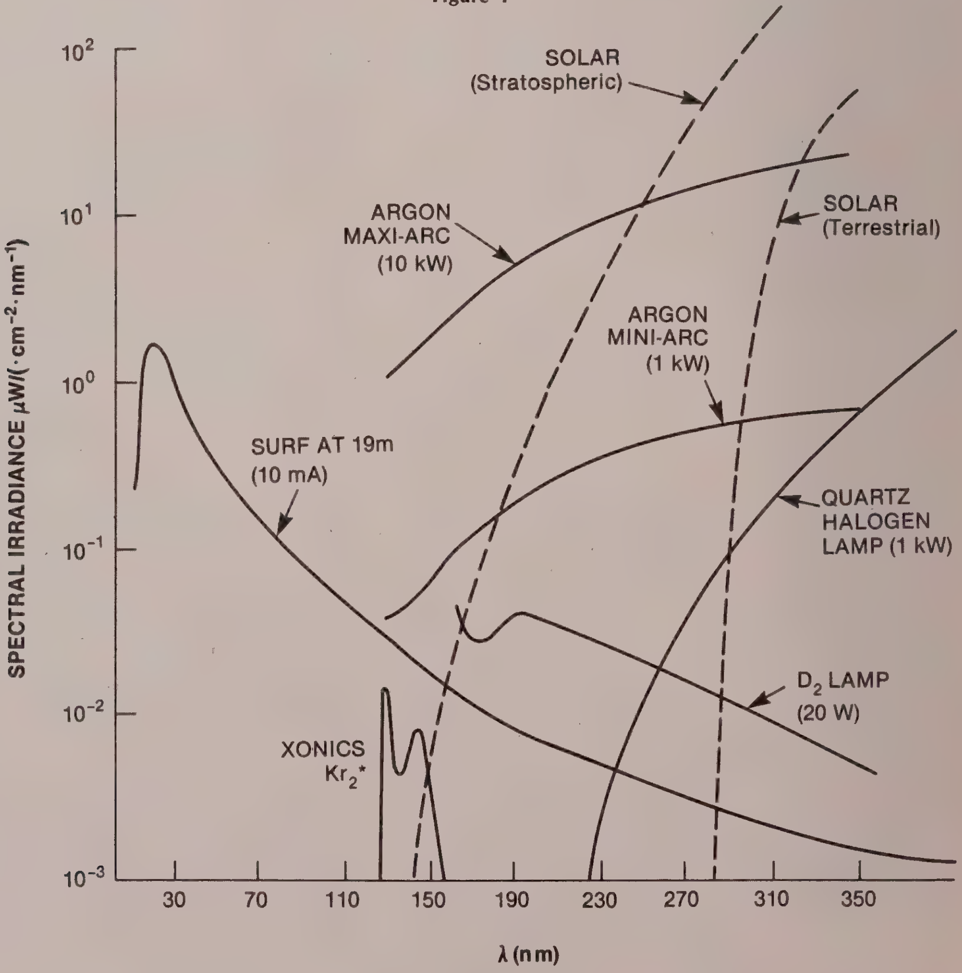
* *The identification of commercial equipment or materials does not imply recommendation or endorsement of these products by NBS.*

Figure 1



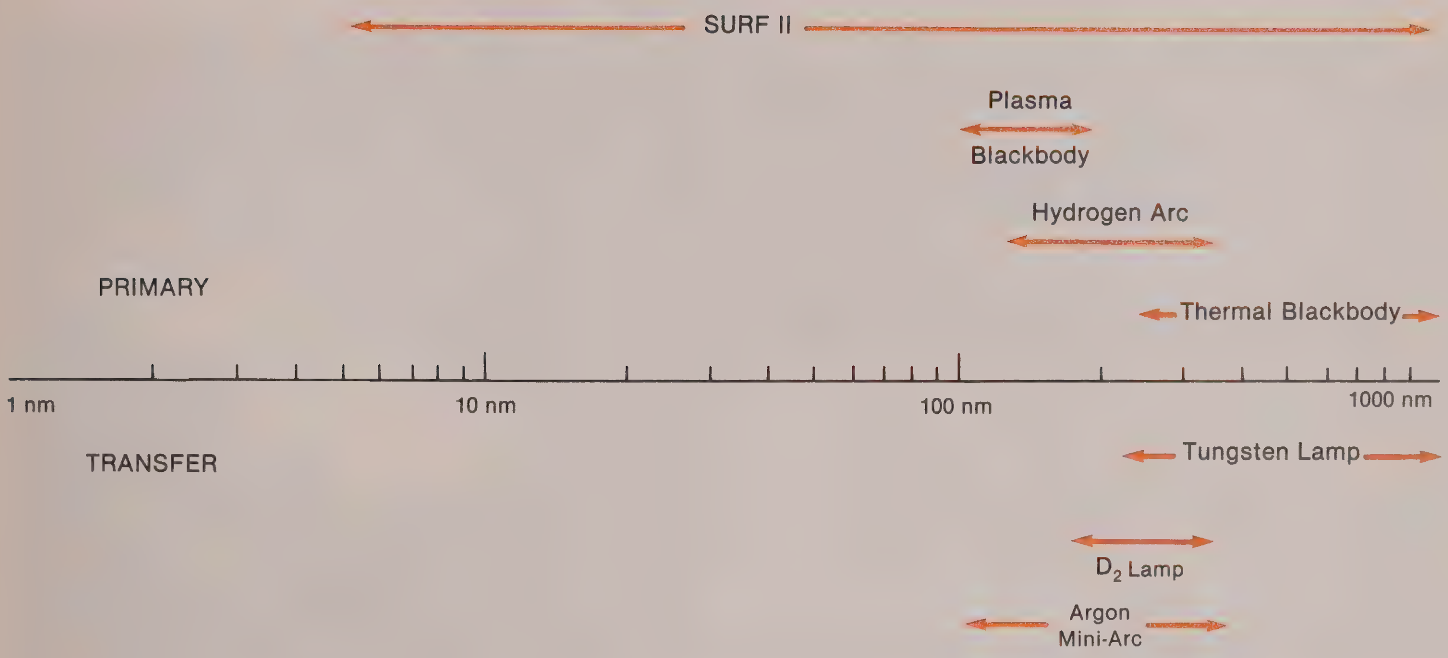


Figure 2

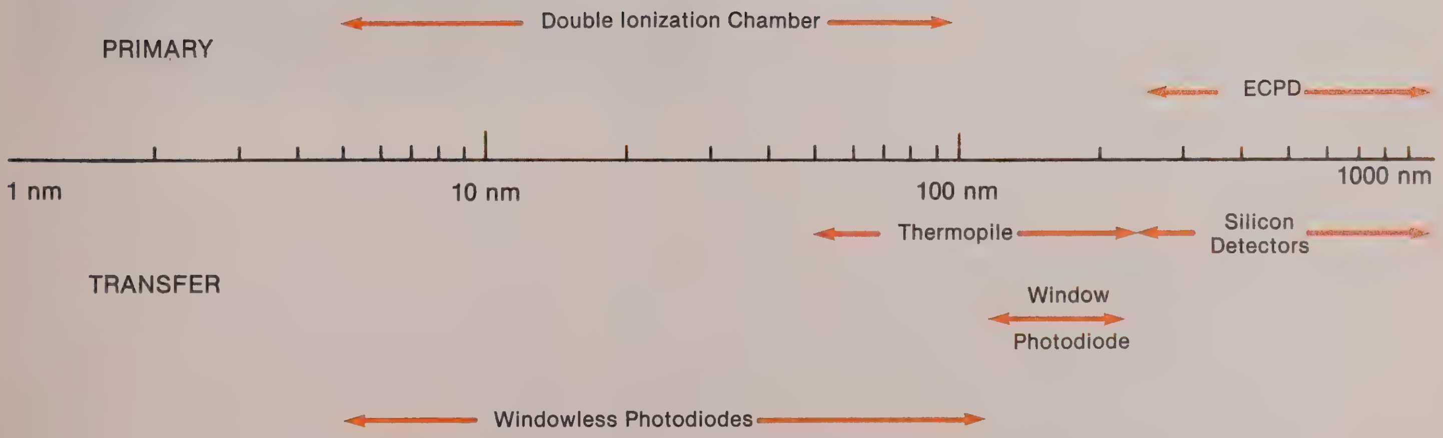


Figure 3

LIQUEFIED NATURAL GAS:

An Energy Alternative

by Gail Porter and Kent Higgins

ENERGY. America just can't get enough of it. In the past, natural gas has been one of our most dependable fuels. Accounting for 25 percent of U.S. energy consumption, natural gas is one of the cleanest, most economical fuels we have.

But soon we will have less of it. In 1976, U.S. production of natural gas satisfied 95 percent of our natural gas needs. By 1980, the American Gas Association (AGA) predicts that figure will drop to 85 percent and then drop again to 70 percent by 1985.

Keeping America's gas pipelines filled to the necessary levels will require hefty transfusions from other countries. Last year, almost all of our imported natural gas was transported through pipelines from nearby Canada. In the future, though, an increasing amount of our natural gas will come from places as far away as Algeria and Libya. And it will reach the U.S. not as a gas at all, but as a liquid.

Liquefied natural gas or LNG is a relatively new approach for helping to relieve the wordwide energy crisis. Its main advantage over regular natural gas is that it can be transported and stored more economically. Cooled to the point of liquefaction (about −162 °C) natural gas occupies only 1/600 of its original volume. Unlike regular natural gas which must be transported through pipelines, LNG can be shipped in large tankers similar to those used to carry oil.

Only about 10 countries in the world have taken advantage of the technology needed to buy and sell LNG. Of these, the U.S. is the second largest importer of the fuel, exceeded only by Japan. According to AGA estimates, the amount of LNG imported

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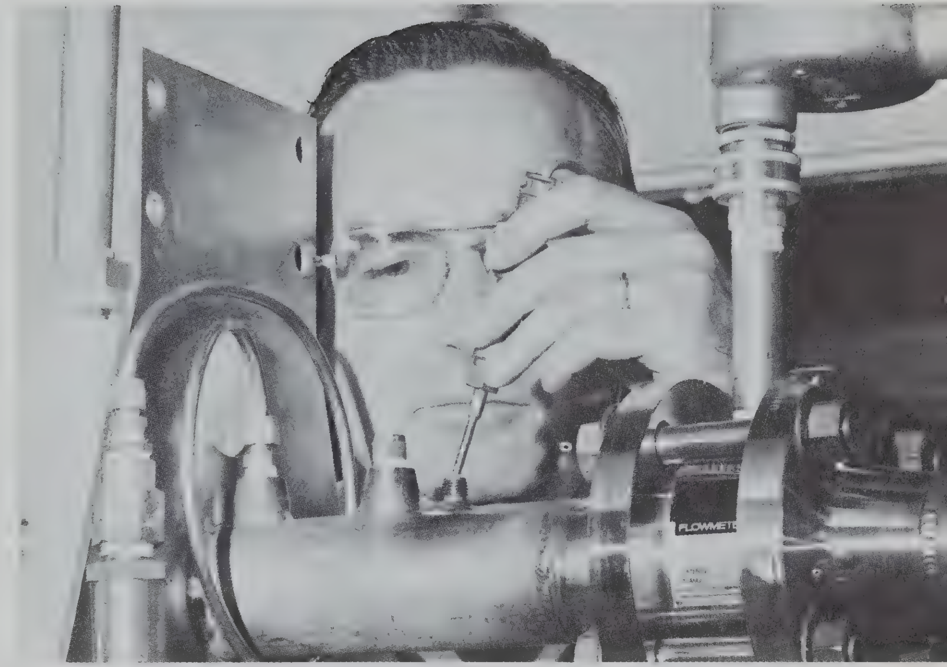
by the U.S. will increase from less than one percent of our total natural gas consumption to over 12 percent by 1990. In short, the business of importing LNG is destined to balloon dramatically over the next decade.

All of these facts mean the U.S. has a large stake in insuring that LNG is bought and sold equitably. Without reliable methods for measuring the total heating value of an LNG shipment, it is impossible for importers to be sure they are paying the right amount for the LNG they buy. Because LNG is shipped in massive quantities, even a small percentage of error in these measurements could mean thousands of dollars of difference in the price of any one shipment.

Using current measurement techniques, the amount of potential error in LNG measurements may be as much as five to seven percent of the total value of each shipment. This year alone, U.S. gas companies plan to import over $16 billion worth of LNG. With a measurement uncertainty of five percent per shipment, the potential loss to the U.S. could amount to $225 000 each day or over $82 million each year.

In 1970, researchers at the National Bureau of Standards laboratories in Boulder, Colorado, initiated a program to define and if possible to decrease the uncertainty in measuring LNG shipments and thus increase the confidence of U.S. importers that they were getting what they paid for. Based on previous research with other extremely cold or cryogenic liquids, the Bureau began the painstaking task of compiling the kind of specialized reference data needed before accurate measurements of LNG could be made. At the same time, alternative methods of measuring LNG quantity and quality were tested.

As a result of this nine-year research effort, scientists of the NBS Thermophysical Properties Division and representatives of the American Gas Association (AGA), an industry trade association, submitted last year an extensive draft of recommendations to the International Organization of Legal Metrology (OIML).* If adopted, these recommendations would establish standard measurement methods and techniques for all transfers of cryogenic fluids including LNG among OIML's 43 member nations. Right now, there are no internationally agreed upon standards. Naturally, if the buyer and the seller of LNG are using different methods of measurement, they are more likely to disagree on how much a particular shipment is worth. Standardizing these techniques would go a long way towards eliminating this aspect of measurement uncertainty.



Mechanical engineer James Brennan inserts a probe into a flowmeter used for volumetric measurements of cryogenic liquids.

In the meantime, the results of NBS research are being transferred to the U.S. gas industry as they become available. During the past two years, for example, NBS research has made possible an estimated 40 percent improvement in the uncertainty of LNG properties measurements. The improvements stem from a better understanding of basic LNG thermophysical properties and measurement methods in four different areas—the completion of density measurements of the various LNG component gases and gas mixtures to an accuracy of 0.1 percent; the refinement of methods to measure the volume of an LNG shipment with larger, more accurate flowmeters; the completion of calibration methods and standards for commercial density measurement systems; and substantial improvement of LNG sampling and analyzing procedures.

To better understand how all of these complex factors combine to produce more accurate measurements consider the importation of a single shipment of LNG. The chain of events begins at the foreign source of natural gas, such as Arzew, Algeria. At Arzew, the gas is repeatedly compressed and cooled

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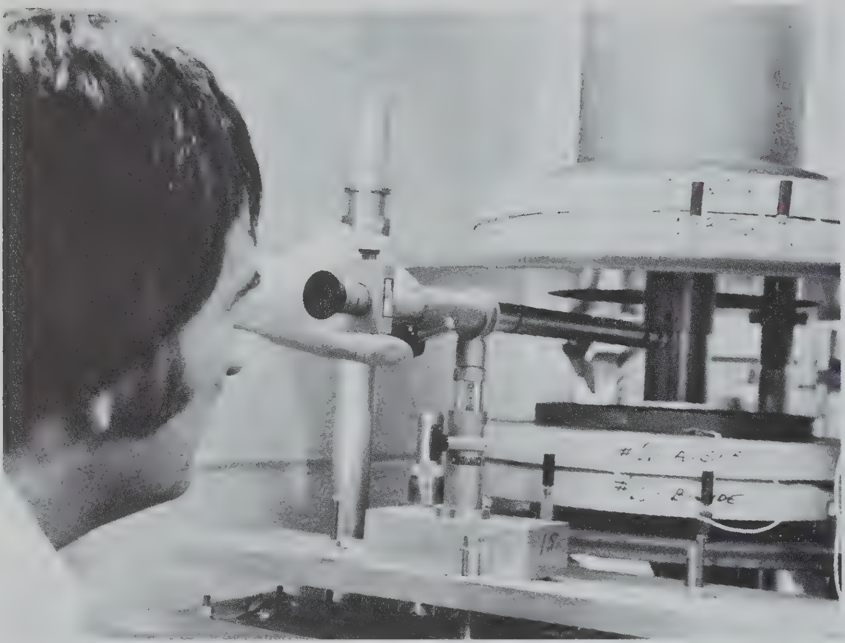
** The mission of OIML is to promote international cooperation in the field of legal metrology, including compatibility of standards of measurement and the laws or regulations which affect them.*



Physicist William Haynes determines the density of a pure fluid component of LNG using a magnetic suspension densimeter which was developed at NBS.

until it liquefies. Now in the form of LNG, it is stored in large insulated holding tanks.

When a shipment of LNG is needed, the fluid is piped from the holding tanks into the tanks of an LNG carrier vessel. (See photo, page 14). Typically, one shipment of LNG will have a volume of 125 000 cubic meters. That's enough LNG to cover an American football field to a height of 30 meters (100 ft.)

Before the LNG carrier ship leaves the loading dock, the seller of the fuel needs to know both the quality and the quantity of shipment in order to establish a total price. In the most common measurement approach in use today, (known as the static method), the quantity of LNG is determined by measuring both the volume and the density of the fuel at specific time intervals.

Volume measurements are made using electronic sensing devices to note the level of liquid in the ships tanks both before and after loading. The difference in height between the before and after measurements is then related to the total capacity of the tanks which have been measured precisely. (See story on page 19).

LNG density measurements may be made using either inferred or direct measurement methods. In the first of these, a sample of the LNG is vaporized or heated to its gaseous state. The sample is sent through an instrument called gas chromatograph where its component gases are identified. Some of the common liquefied natural gases include methane, ethane, propane, butanes, and nitrogen. Natural gas from different sources will be a mixture of these gases in various proportions. For example, samples of natural gas from Alaska are considerably different than those from Libya. Alaskan samples analyzed by NBS consisted of 99.6 percent methane and 0.4 percent nitrogen. Libyan samples, in contrast, consisted of 70 percent methane and smaller proportions of ethane, propane, and butane. Once the pure gas components of the LNG have been identified, the average density of the shipment can be calculated based on NBS standard reference data about the density of each of these gases under conditions of known temperature and pressure.

The alternative method involves the direct measurement of the shipment's density using a densimeter. At least five different kinds of densimeters, operating on different principles are in use by the gas industry.

Combining the liquid level volume reading with the density of the LNG, whether inferred or measured, will tell the shipper how much LNG is being sold.

Establishing the quality of the shipment is equivalent to determining the heating ability of the LNG and this also depends on the proportion of pure gases in the liquid. Some gases produce more heat for each unit of volume than others. If the density of the LNG shipment has been determined using the inferred method, the shipper will already know the composition of gases in the fluid. Using standard reference data provided by NBS, the shipper can calculate how much heat a particular shipment of LNG will produce when burned, based on the known heating ability of its pure gas components.

Another more direct way of assessing the quality of the shipment is to take a sample of the fluid and burn it in an instrument called a combustion calorimeter. The combustion calorimeter will measure the heat given off based on the standard international unit for joules produced per kilogram of a substance burned. Using an average value for the entire shipment, the seller could determine the total sales price of the shipment by combining the mass (volume and density) and the average calories per kilogram to calculate the total potential calories in the shipment.

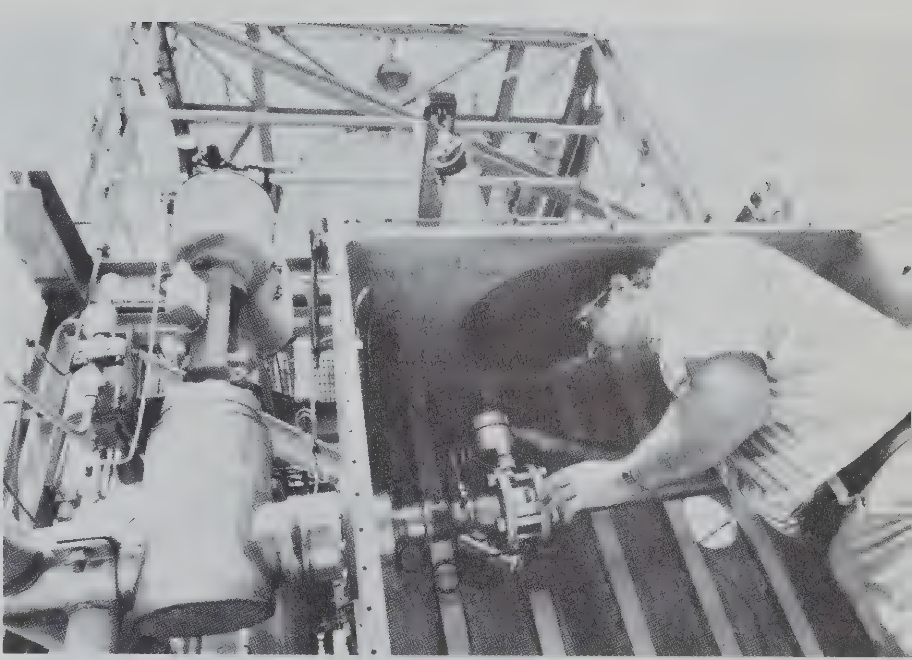
Arriving at its port of destination, all three measurements will be taken before, after, and possibly at specified times during the unloading of the fuel at a U.S. receiving terminal. It is quite possible that the combination of measurement methods used at the receiving terminal will be different from the one used at the time of loading. More likely than not, the buyer and seller will disagree on the total commercial value of the shipment. These differences will be settled using an agreed method of averaging which is stated in the sales contract.

But even if the measurement methods at both the shipping and receiving ends were identical, an LNG importer would still not be confident that the amount measured at the loading dock will necessarily be the same amount to arrive at the final destination. Like the skin of a chameleon which is constantly changing to reflect its environment, the essential variables for measuring the commercial value of LNG are in a constant state of flux. Changes in temperature and pressure within the tanks during the voyage will be translated as a difference in the shipment's volume and density, while evaporation of the more volatile natural gases may change the proportion of pure gas components appreciably enroute.

To minimize the effect of these changing variables on the determination of the shipment's true value, NBS is also studying a dynamic measurement method rather than the static approach described above. Instead of making measurements at specified intervals, both the buyer and seller using a dynamic approach would be making continuous measurements of all three main variables throughout the loading and unloading of the fuel. NBS has assessed a three-element measuring system known as a therm meter which includes a volume measuring flowmeter, a direct reading densimeter, and a combustion calorimeter. With this system both the quality and the quantity of an LNG shipment can be measured continuously and simultaneously.

The big advantage of the therm meter system is that it allows continuous control over the whole measurement process. Measurements made with a well calibrated LNG therm metering system would allow determination of the actual heating value of an LNG shipment, with a known amount of uncertainty. Without the continuous control of such a system, the accuracy of a measuring system can only be estimated with an educated guess.

There is, however, one remaining "bug" in the system. Before accurate LNG measurements will be possible using the dynamic method, large volume measuring flowmeters must be developed and calibrated against established NBS standards. The massive size of the LNG tankers dictates the need for large diameter piping systems which will transport the fuel quickly. The faster a tanker of LNG can be unloaded, the faster it will be able to return to sea to pick up a new shipment.



Brennan inspects a test flowmeter at the Boulder outdoor LNG testing facility. LNG is piped from one storage tank through the flowmeter being calibrated and then contained in a second tank for future testing.

Cryogenic flowmeters were originally designed to measure other industrially used fluids such as oxygen, hydrogen, argon, and nitrogen which are bought and sold in much smaller quantities than LNG. These flowmeters, which have been extensively tested by NBS since 1968, are only about 10 cm in diameter. NBS has devised a scaling law based on actual measurements at LNG terminals that allows the calibration of flowmeters up to 30 cm in diameter. The pipes used by the LNG shipping industry, however, are up to 90 cm in diameter. Additional calibration measurements at field sites using larger flowmeters must be made before the dynamic method can be used reliably.

Meanwhile, the results of NBS basic thermophysical properties research which have immediate effects on the measurement of LNG have been made available to the gas industry through the "LNG Materials and Fluids Manual" published in November 1977, and the supplement to the manual published in the following year. This award-winning publication includes comprehensive listings on all of the significant thermophysical properties of LNG. Described in detail are pressure, density and temperature relationships, transport properties, thermal conductivity, and other thermodynamic character-

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* *Copies available by contacting the Cryogenic Data Center, National Bureau of Standards, Boulder, Colo. 80303, 303/499-1000, ext. 3125.*

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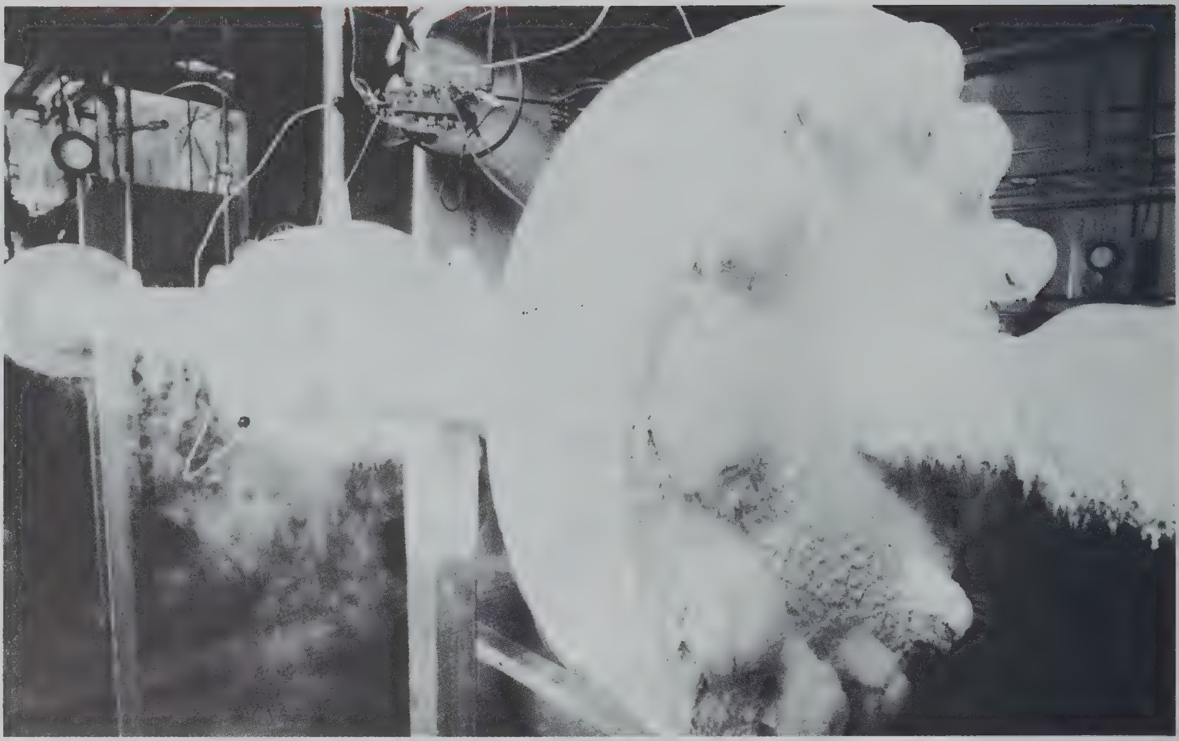

Ice cakes a 10 cm LNG flowmeter during a liquid nitrogen (—195 °C) calibration test at the NBS/Boulder cryogenic and flowmetering research facility

istics, electromagnetic properties, as well as the thermal and mechanical properties of metals and insulation materials used in LNG tankers.

In addition, these publications include updated tables of precise density measurements for the pure fluids of methane, ethane, propane, butane, nitrogen and commonly occurring mixtures of these gases throughout the temperature range of 105 to 140 K (−168 °C to −33 °C).

The improved density measurements have also been the basis for the development of an NBS reference system for calibrating the main types of densimeters in current use. The American Gas Association asked NBS to create this reference system to help the gas industry in calibrating commercial LNG densimeters. The system includes a LNG fluid mixture of known density which can be subjected to conditions of varying temperatures and pressures. Industry densimeters are placed in this system and their readings are compared to an NBS densimeter which has been calibrated in terms of the reference fluid. In the near future, NBS researchers hope that individual gas companies will be able to calibrate their own density reference systems using an NBS transfer standard, a unit which includes a portable reference system.

Finally, as long as the static measurement method remains the most reliable one available, there is a need to know how well sampling procedures for density and gas chromatography analysis represent the contents of a shipment. NBS has defined the precision for different types of sampling and analysis. This information will allow the gas industry to better calculate the total measurement uncertainty for a particular sampling and analysis system and to choose those systems with the greater precision.

In all of these LNG research projects, NBS scientists strive for methods which produce results in the laboratory with only 0.1 percent measurement uncertainty. Laboratory measurement methods are generally 10 times more accurate than the corresponding field measurements. The ultimate goal of the NBS LNG Thermophysical Properties program, then, is to reduce total uncertainty in LNG measurements from the current estimates of from five to seven percent to a much more tolerable one percent potential error per shipment.

The joint NBS/AGA submission of draft recommendation to OIML is the first major step toward achieving that goal for international LNG exchanges. As the volume of LNG international trade expands to make LNG one of our major sources of energy, it will surely be a step with increasing economic significance.

ON LINE WITH INDUSTRY

ASSESSING LNG TANK VOLUME CALIBRATIONS

by Kent Higgins and Michael Baum

Scientists from the National Bureau of Standards are assessing the accuracy of the surveying techniques used by the liquefied natural gas (LNG) industry to calibrate the volumes of shipboard tanks used to transport LNG.

Working in cooperation with the Commerce Department's Maritime Administration and an industrial organization known as the LNG Custody Transfer Measurements Supervisory Committee*, researchers from the NBS Thermophysical Properties Division in Boulder, Colorado, and the Mechanical Processes Division in Gaithersburg, Maryland, are providing an independent evaluation of the photographic measurement techniques used by shipbuilders and their private consultants to measure LNG tank volumes.

The commercial measurement of liquefied natural gas presents unique metrology problems because of the extremely low temperature of the fluid (approximately −162 °C). Flow meters are not used because commercial LNG pipe sizes run to 42 inches (110 cm) in diameter and there are no existing facilities to calibrate cryogenic flow meters for pipes over 4 inches (10 cm) in diameter.

Instead, the builders of the special LNG tankers provide volume calibrations for each ship's tanks. The shape and dimensions of each insulated tank are reduced to a "tank table" that records liquid volume as a function of the height of the liquid in the tank.

The tanks, constructed of welded metal plates, are huge. Modern LNG tanks stand 23 meters high and the largest have widths and lengths of about 37 meters. A set of tanks for a current-generation LNG carrier has a total volume of approximately 125 000 cubic meters of LNG. At these sizes, and current prices, a 1 percent volume error for the tanks aboard one LNG carrier translates as a $60 000 loss (or gain) for each shipload. With each LNG carrier making 15 to 20 annual trips to the United States the error soon becomes economically significant.

There are three different basic designs for LNG tanks: spherical, prismatic (see photograph), and membrane tanks. (The latter are basically prismatic in shape but differ from rigid prismatic tanks in that they are not free-standing—they depend on the surrounding insulation and the ship's hull for support.)

The calibration method for these tanks is the so-called photogrammetric survey technique. The surveyor takes a series of high-resolution photographs of the outside of the tank after it is constructed and tested, but before it is placed in the ship's hull. "Targets" or identifiable marks and a calibrated rule on the walls of the tank allow the photographs to be analyzed by a complex procedure that yields a set of coordinates from which the dimensions of the tank can be calculated. (The system is an analog of classical surveying techniques.) This information, together with corrections for distortion caused by the camera lens, volume lost to internal braces in the tank, the known change in the volume of the tank at cryogenic temperatures, and similar factors, gives a volume for the tank that is estimated by the surveyor to be within 0.1 percent of the true value.

Currently, four U.S. shipyards are building 20 LNG carriers. The ship builders rely on private surveyors to calibrate the tanks. NBS was requested to provide an impartial test of the accuracy of the calibration method—an assurance that often becomes important in dealing with foreign producers of LNG.

"One problem in assessing the photogrammetric survey technique," according to NBS physicist and project coordinator James Siegwarth, "is that it is hard to find a more accurate method to test its accuracy." Another consideration is that the exact computer techniques used by the private photographic surveyors to analyze their photos are trade secrets.

In essence, the NBS researchers checked the photographic method by feeding known values into the system and checking the results. NBS photographic targets clamped to invar surveyor tapes were added to the other targets on the tank walls, usually six to eight sets of targets for each tank. The positions of the targets were noted relative to scribed lines on the otherwise unruled invar tapes. (Unruled tapes were used to insure that the correct distance was marked between the targets. Invar tapes were used for their resistance to thermal expansion, even though temperature corrections were made for the tapes at the time of the photography.)

The tapes were returned to the NBS mechanical properties laboratories to be measured with laser interferometers. The surveying company, treating the NBS photographic targets like the other targets, supplied the calculated coordinates for the position of the targets on the wall of the tank. Comparison of the calculated distance between two targets with the distance measured by the invar tapes and the NBS laboratories tested both the precision and the accuracy of the surveyor's photographic data.

When the accuracy and precision determined by the tape measurements were combined with other sources of uncertainty such as temperature effects, volume calculations, targets placement, and loading distortions, then the calculated error of the photogrammetric calibration method was found to be within the surveyor's estimated 0.1 percent uncertainty.

Higgins is a writer and public information specialist with the NBS Boulder Program Information Office and Baum is a writer and public information specialist in the Public Information Division.

* *The members of the committee are from El Paso Marine Company, Columbia LNG Corporation, Consolidated Systems LNG Company, and Southern Energy Company.*

STAFF REPORTS

Frequency Measurement, p. 20
Thermophysical Properties, p. 23
Super Spring, p. 25

FIRST DIRECT FREQUENCY MEASUREMENT OF VISIBLE LIGHT REPORTED

A joint effort between the National Bureau of Standards and the Canadian National Research Council (NRC) has produced the first direct measurement of the frequency of yellow-green visible light—the highest frequency measurement ever made. The measurement links the second harmonic of a helium-neon (He-Ne) laser stabilized in iodine vapor at 520 THz to the primary standard of frequency, a cesium resonance at 9.193 GHz. This achievement paves the way for super accurate frequency measurements in the visible area of the electromagnetic spectrum, and opens wider the possibility of redefining the meter in terms of the second, thus fixing the speed of light at a defined, rather than measured, value.

Kenneth M. Evenson, D. A. Jennings, and F. R. Petersen, Time and Frequency Division, Room L-3540, NBS, Boulder, Colo. 80303, 303/499-1000, extension 3397.

At its recent meeting in Paris, the Consultative Committee for the Definition of the Metre recommended that the meter be defined as the distance travelled by light in 1/299 792458 seconds. A prerequisite for realizing such a standard, which connects length measurements to frequency measurements through the defined value of the speed of light, is to bridge our ability to relate visible light frequencies to frequencies used to define the second. The frequency of the cesium atom used to define the second is 9.193×10^9 Hz and the length standard operates in the visible at 4.95×10^{14} Hz.

The joint NBS-NRC experiment was conducted by K. M. Evenson, D. A. Jennings, and F. R. Petersen of the NBS Boulder, Colorado, laboratories and K. M. Baird and G. Hanes of NRC at Ottawa. The work consisted of a comparison of the two highest frequency lasers, in a chain of successively higher frequency lasers.

Each laser in the chain was measured by beating its radiation against a harmonic of the next lower frequency or against the sum of two or more known lower frequencies. The radio frequency beats produced in this process are low enough to be measured using ordinary frequency-counting techniques. Thus, each laser's frequency becomes known in terms of the already measured lower frequencies, plus or minus the measured beat frequency.

The chain of measurements required 14 lasers and 6 klystrons (microwave generators). The first 13 measurements were done at NBS, and resulted in a known frequency for the 260 THz pure Ne laser. This NBS laser was taken to Ottawa, where the NRC had a He-Ne laser combined with a lithium niobate ($LiNbO_3$) frequency-doubling crystal. The NRC device produces light at both 260 THz and the exactly doubled frequently of 520 THz.

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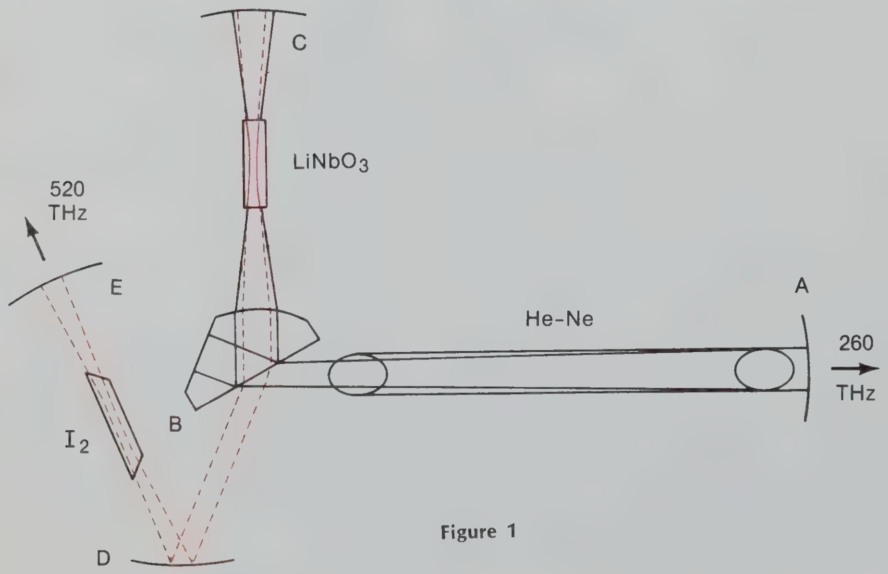
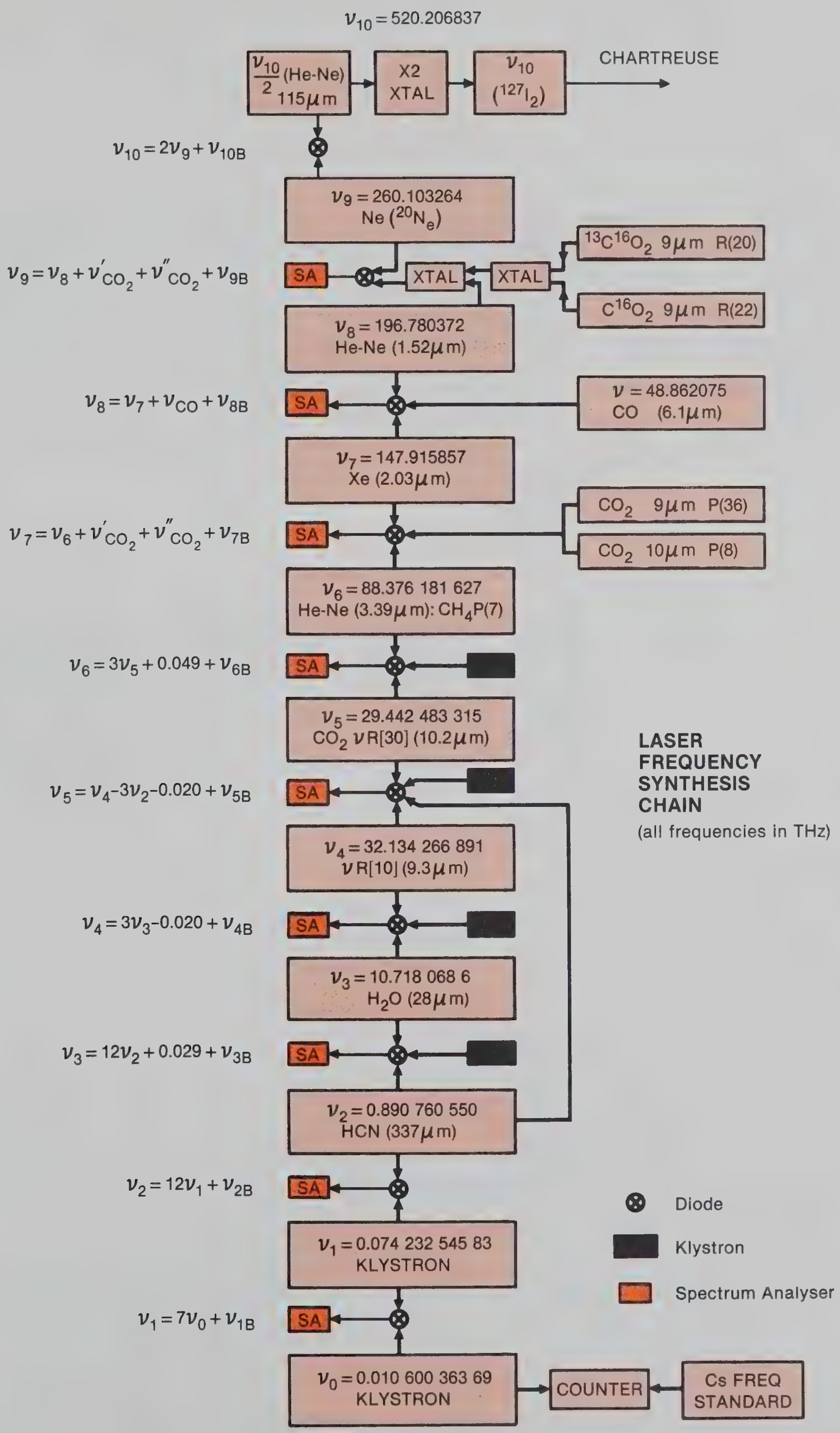


Figure 1

Figure 1—*The layout of the NRC composite cavity laser used to produce saturated absorption in iodine-127 at twice the He-Ne frequency of 260 THz (1.15 μm). The 260 THz is produced in arm AB, and arm CB is closely coupled to AB by reflectance at prism B. Meanwhile, cavity CBDE is resonant at 520 THz. Servos at mirrors C and E keep all three arms in resonance and provide turning over a range of about 2.5 GHz at 520 THz, easily allowing the observance of many hyperfine lines in iodine-127.*

Figure 2—*Laser Frequency Synthesis Chain. The two lowest frequency diodes (at the bottom) are silicon diodes and the two highest ones are photodiodes. The others are tungsten-on-nickel catwhisker diodes. The diodes are used as both harmonic generators and mixers. The crystal used to mix the two 9-μm CO_2 lasers [R(20) and R(22)] is cadmium germanium arsenide ($CdGeAs_2$) and the crystal to its left is proustite (Ag_3AsS_3). The "X2 XTAL" at the top is the $LiNbO_3$ doubling crystal of the NRC device.*


$\nu_{10} = 520.206837$
$\frac{\nu_{10}}{2}$ (He-Ne) 115μm
X2 XTAL
ν_{10} ($^{127}I_2$)
CHARTREUSE
$\nu_{10} = 2\nu_9 + \nu_{10B}$
$\nu_9 = 260.103264$ Ne ($^{20}N_e$)
$^{13}C^{16}O_2$ 9μm R(20)
$C^{16}O_2$ 9μm R(22)
$\nu_9 = \nu_8 + \nu'_{CO_2} + \nu''_{CO_2} + \nu_{9B}$
SA
XTAL
XTAL
$\nu_8 = 196.780372$ He-Ne (1.52μm)
$\nu_8 = \nu_7 + \nu_{CO} + \nu_{8B}$
SA
$\nu = 48.862075$ CO (6.1μm)
$\nu_7 = 147.915857$ Xe (2.03μm)
CO_2 9μm P(36)
CO_2 10μm P(8)
$\nu_7 = \nu_6 + \nu'_{CO_2} + \nu''_{CO_2} + \nu_{7B}$
SA
$\nu_6 = 88.376\ 181\ 627$ He-Ne (3.39μm): CH_4P(7)
$\nu_6 = 3\nu_5 + 0.049 + \nu_{6B}$
SA
$\nu_5 = 29.442\ 483\ 315$ CO_2 νR[30] (10.2μm)
$\nu_5 = \nu_4 - 3\nu_2 - 0.020 + \nu_{5B}$
SA
$\nu_4 = 32.134\ 266\ 891$ νR[10] (9.3μm)
$\nu_4 = 3\nu_3 - 0.020 + \nu_{4B}$
SA
$\nu_3 = 10.718\ 068\ 6$ H_2O (28μm)
$\nu_3 = 12\nu_2 + 0.029 + \nu_{3B}$
SA
$\nu_2 = 0.890\ 760\ 550$ HCN (337μm)
$\nu_2 = 12\nu_1 + \nu_{2B}$
SA
$\nu_1 = 0.074\ 232\ 545\ 83$ KLYSTRON
$\nu_1 = 7\nu_0 + \nu_{1B}$
SA
$\nu_0 = 0.010\ 600\ 363\ 69$ KLYSTRON
COUNTER
Cs FREQ STANDARD
⊗ Diode
■ Klystron
🟧 Spectrum Analyser

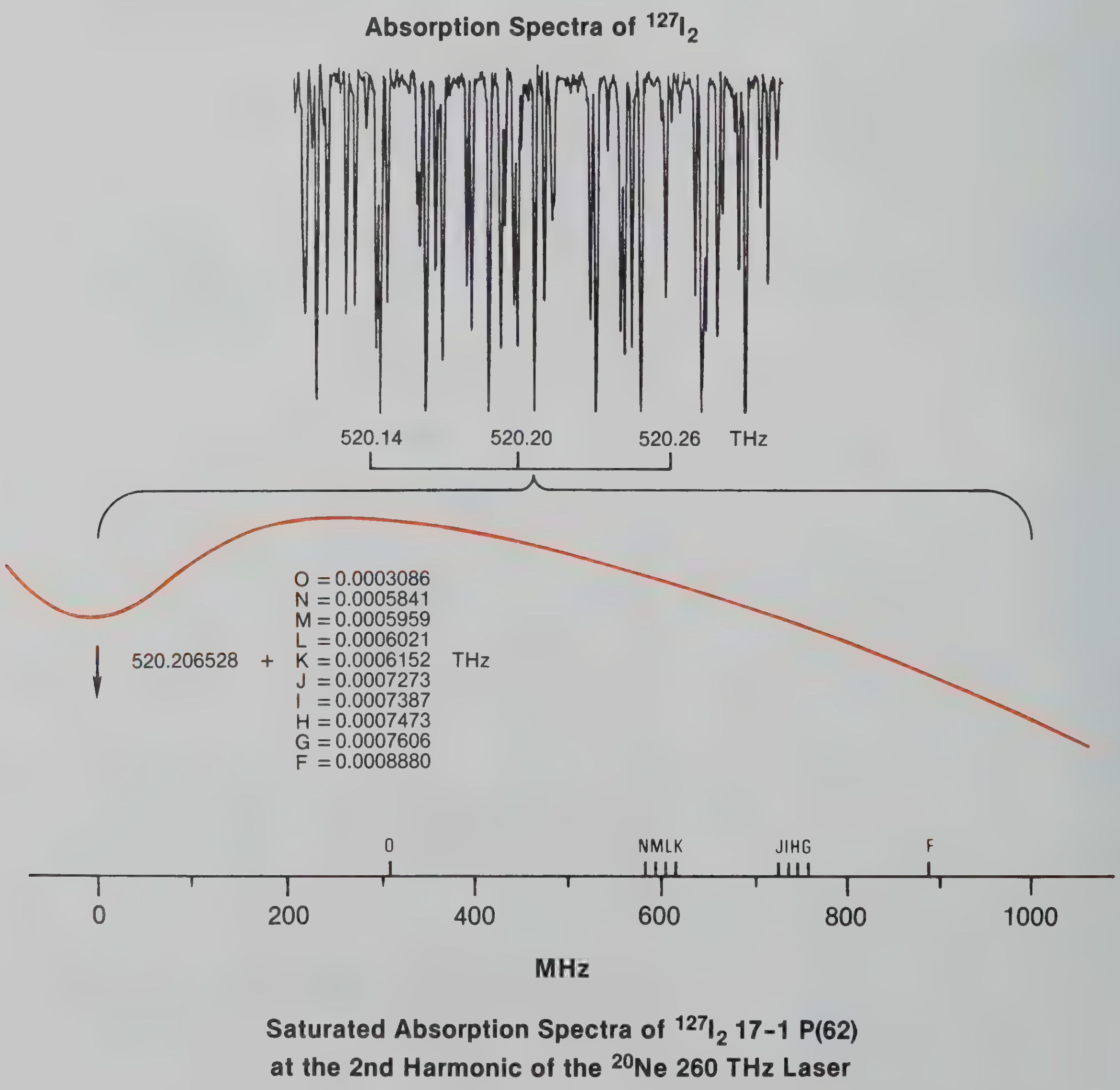
LASER FREQUENCY SYNTHESIS CHAIN
(all frequencies in THz)

Figure 2

The doubled-frequency can be servo-locked to individual hyperfine components of iodine-127. Then, by beating the NBS 260-THz radiation with the NRC 260-THz radiation and measuring the beat frequencies, the iodine frequencies were also measured.

The objective of the experiment was to demonstrate the feasibility of reaching the visible spectrum using only frequency-counting techniques, which are inherently the most accurate known for measuring physical phenomena. A future experiment will be aimed at achieving high accuracy and precision. With the use of stabilized lasers throughout the chain, it should be possible to determine the iodine frequencies to the accuracy of the cesium time standard, or one part in 10^{13}: this would be about 1000 times better than the best accuracy achievable with wavelength measurements.

Figure 3—*The upper trace (a) shows the overall absorption of iodine near 520 THz. One of these lines (arrow) is resolved in saturated absorption in the lowest trace (C) into ten hyperfine components labelled F through O. Component O has the best signal-to-signal ratio and occurs near the maximum power of the laser, and thus may have the most potential for selection as the line of greatest interest for further work. The middle curve (B) graphs the relative power of the Ne laser after doubling to 520 THz. The center frequency of this laser is at 0 in the MHz scale.*



Absorption Spectra of $^{127}I_2$

Saturated Absorption Spectra of $^{127}I_2$ 17-1 P(62) at the 2nd Harmonic of the ^{20}Ne 260 THz Laser

GENERIC TECHNIQUE FOR ACCURATELY PREDICTING THE THERMOPHYSICAL PROPERTIES OF FLUID MIXTURES

The National Bureau of Standards continues to increase its basic competence in specific fields. Special competence building initiatives are being undertaken where scientific solutions compatible with the NBS mission appear possible and where the underlying scientific foundation appears ripe for advancement. One area chosen for 1979 competence building, experimental fluid mixtures, is described here.

Neil Olien, Thermophysical Properties Division, Boulder, Colorado, Building 2-0123, 303/499-1000, ext. 3257.

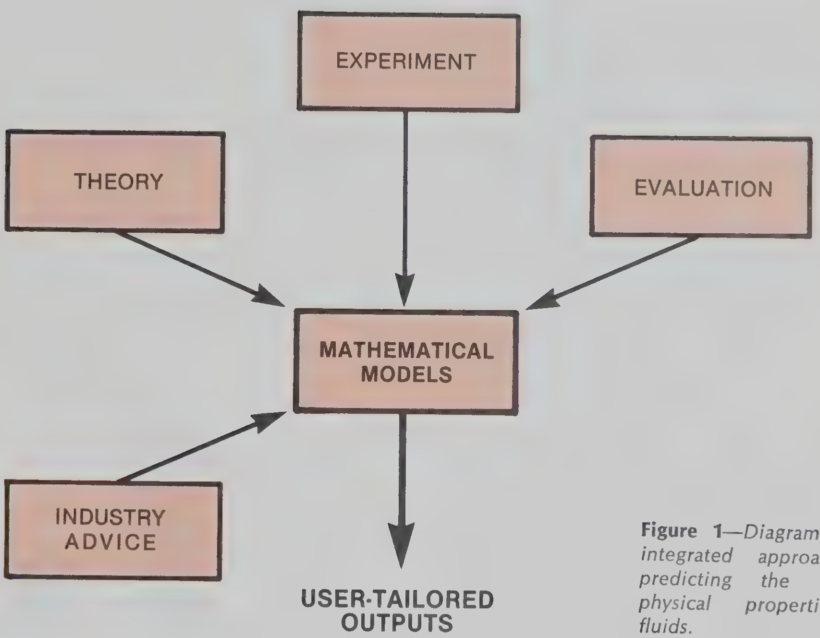


Figure 1—*Diagram of an integrated approach for predicting the thermophysical properties of fluids.*

For many people, prediction is equated with prophecy; however, prediction based on sound models can offer solutions to problems of great importance. Fluid mixtures are ubiquitous quantities in nearly all sectors of modern industrial society, and, in many cases, accurate knowledge of their properties can significantly reduce the capital cost and increase the operating efficiency of the processes in which the mixtures are involved. Unfortunately, we find that the variability of uses of mixtures is exceeded by the compositions of the mixtures themselves. Thus, one is faced with a requirement for a veritable ocean of fluid property data. An obvious answer is to develop a means of representing the mixture mathematically, so that accurate predictions can be made. Numerous models have been developed, but all have limited usefulness.

At NBS, we have embarked on a long-range program to provide more general solutions to these problems. It would be presumptuous to aim at developing a single model for the universe of fluid mixtures, but we do feel that it is feasible to try for significant advances over the present state of affairs. Our approach is a consciously integrated study of fluid behavior and the attendant thermophysical properties (see Figure 1). Rather than attack the problem on one front (obviously a purely experimental approach would involve an infinity of measurements), we will be combining experimental, theoretical, and mathematical modeling studies. One point is clear; the entire program will be measurement-limited, so that the experimental efforts will have to be selected with utmost care. The data taken will have to be of high quality; the literature is replete with examples of data of doubtful quality which are of no help in advancing theory or improving predictive models.

The rationale of the program is soundly based on experience gained in a long-term effort on natural gas properties and on a soon to be completed government-industry ethylene project. The latter was managed by the NBS Office of Standard Reference Data and included significant contributions from the Gaithersburg-based NBS Thermophysics Division. We are continuing the collaboration with these two organizations in the program described here. As stated, the plan is based on existing expertise; however, the broader scope and more fundamental approach outlined here requires additional expertise. It is to this need that the new competence resources are dedicated. The specific areas to be addressed are:

1. Design and construction of a PVT (Pressure-Volume-Temperature) apparatus to cover the range 300-900 K with pressures to 35 MPa. This will give our laboratory the capability of making precision PVT measurements from 10 to nearly 1000 K. The apparatus will be automated to the extent that is possible at this time. Much of the equipment for this purpose has been received, including a small computer for experimental control and data acquisition, a precision a-c thermometry bridge, and precision digital pressure transducers. Fabrication of sample cells and associated equipment has started, and high temperature ovens/thermostats are on order. We expect to have the apparatus built and performance-tested by late 1980.
2. Development of new techniques for making accurate fluid property measurements by means of laser light scattering. We have done work in this area, and our

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work and work at universities strongly suggests that optical techniques hold great promise for the future. One area of high interest is an investigation of the behavior of the thermal conductivity of a mixture (70 percent methane-30 percent ethane) in the extended region of the liquid-gas critical point. The results of this study have significant theoretical as well as technological implications.

3. Investigations in basic fluid theory. Work is planned on practical applications of conformal solution theory. One goal is quantitative understanding of the interactions between unlike molecules, such as mixtures of polar and nonpolar species.

4. Mathematical modeling investigations ranging from improvements in equations of state to computer simulations of fluid behavior. We plan to expand greatly our present efforts in molecular dynamics studies.

All of these efforts will proceed in concert with existing related work.

At the outset it was indicated that there are many industrial needs for the kinds of predictive tools we plan to develop. Industries which involve fluid mixtures, especially separating fluid mixtures, include synthetic gas processing, coal liquefaction, tertiary oil recovery, air separation, geothermal energy, and water desalination and purification. I will discuss coal gasification here.

It is widely believed that there is a large potential for the use of coal as a substitute for petroleum in the fuel and petrochemical industries. The American Gas Association has projected the capital equipment needs for the gas industry in the period 1978-2000 (see Figure 2). The capital requirement for coal gasification/synthetic natural gas (SNG) for this period is nearly $63 billion. It is obvious that even a small but consistent percentage reduction in capital requirements can represent very large amounts of money. It is generally conceded that the concurrent increase in operating efficiency resulting from better knowledge of property data results in an even greater economic impact. SNG, however, is only one

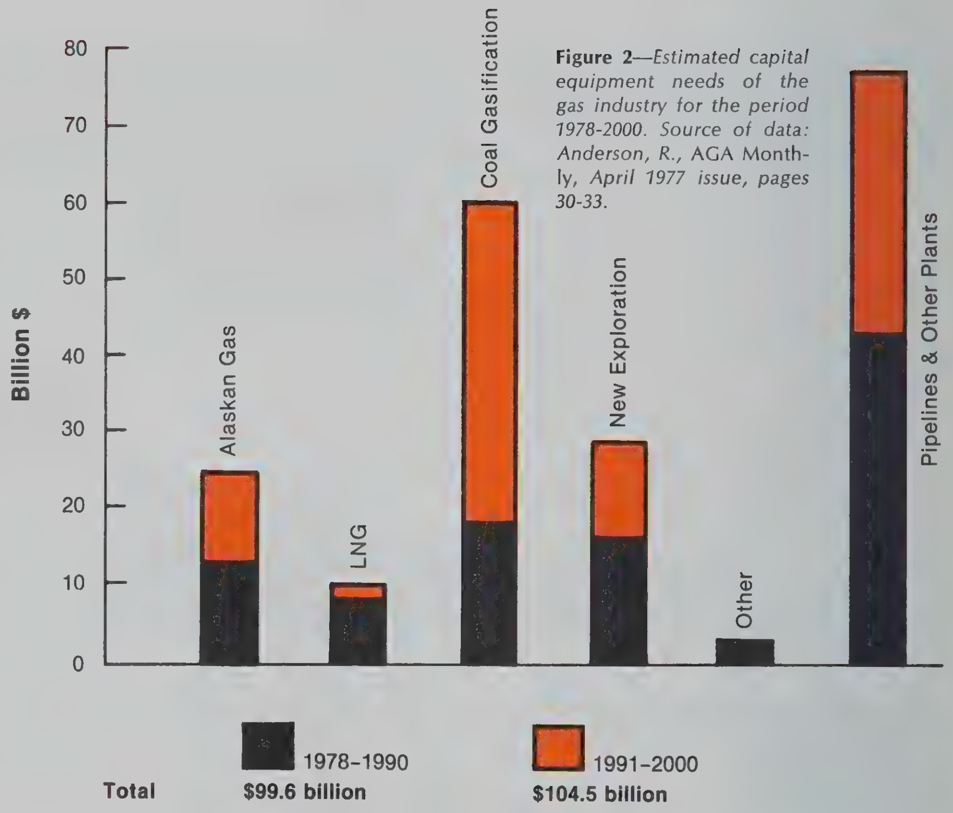
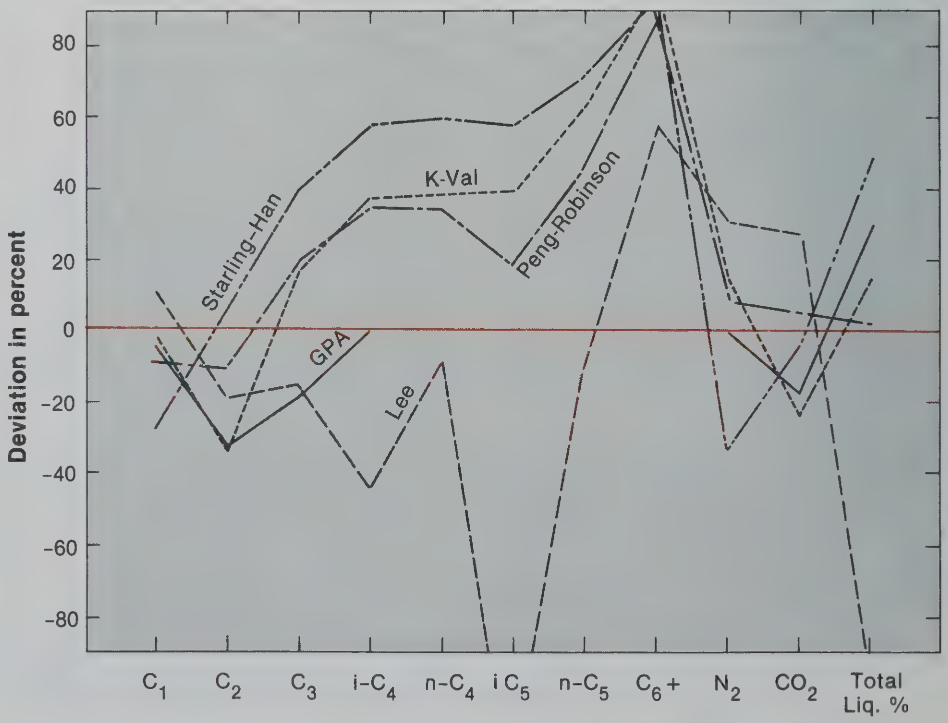


Figure 2—*Estimated capital equipment needs of the gas industry for the period 1978-2000. Source of data: Anderson, R., AGA Monthly, April 1977 issue, pages 30-33.*



industry and may not prove as large a field as projected. Thus it is important that the objective of the NBS program be to develop generic predictive techniques.

As mentioned before, there are a myriad of predictive techniques already in existence, and many are widely used. Why not select the best method and concentrate the effort on it? To illustrate the difficulty of doing that, we present some comparisons of several methods of predicting K-factors for a real natural gas mixture in a real plant. K-factors are a very useful tool to chemical engineers designing plants to separate the constituents of mixtures (e.g., take ethane out of natural gas). K-factor is defined as: $K = \frac{y_i}{x_i}$ where y_i = mode concentration of the ith component in the vapor and x_i = mole concentration of the ith component in the liquid.

Figure 3 presents the deviation of K-factors predicted with five representative calculational methods with a sixth arbitrarily chosen as the baseline. The K-factors are compared for the lower hydrocarbons (C_1 = methane, C_2 = ethane, and so on), nitrogen, carbon dioxide, and finally for the total liquid volume condensed. At this time, we do not know what the true K-factors are for this mixture; but from the disparity shown, truth is not clearly evident in any of the methods compared here. The basic premise of our competence building effort is that a fundamental approach can result in techniques for accurately predicting the thermophysical properties of fluid mixtures. In figure 3, we have a graphic illustration of why better techniques are needed.

Figure 3—*A comparison of five techniques for predicting K-factors for natural gas constituents at 210 °K and 5 MPa in a 2-million cubic meters per day (70 million cubic feet) ethane plant, where ethane and heavier hydrocarbons are separated from natural gas. Source of data: Elliot, D. G. et al., Phase Equilibria and Fluid Properties in the Chemical Industry, ACS Symposium Series 60, T. S. Storvick and S. I. Sandler, editors, American Chemical Society, 1977.*

SUPER SPRING

Isolation of scientific apparatus from vibrations and mechanical disturbances is a long-standing experimental problem. In 1895, C. V. Boys, the eminent British physicist, complained that street traffic hampered his attempts to determine Newton's gravitational constant. Since that time gravitational and high precision experiments have become considerably more sophisticated, but mechanical isolation for many of these experiments still represents a problem. Physicists at the Joint Institute for Laboratory Astrophysics (operated by NBS and the University of Colorado) have developed a new type of device—the so-called "super spring"—to provide that mechanical isolation.

James E. Faller, Joint Institute for Laboratory Astrophysics, A409 JILA, 303/499-1000, ext. 3463, and Robert L. Rinker, Joint Institute for Laboratory Astrophysics, C129 JILA, 303/492-7616.

The super spring makes use of the fact that a mass on the end of a long spring is effectively isolated from vibrations for all frequencies higher than the mass-spring's natural resonance frequency. Thus, systems with the lowest resonance frequency will provide the best isolation. The practical problem is that in order to effectively isolate against the earth's natural microseismic background, the stretched length of a spring must be one kilometer or more.

To understand the super spring concept, imagine a mass hanging on the end of a spring that stretches approximately one kilometer vertically. The mass will oscillate up and down with about a 60-second period. Of course, the individual coils of the spring will also oscillate up and down. The coils close to the mass will have an amplitude roughly equal to the amplitude of the mass; the coils far from the mass will have an amplitude less than that of the mass; and the coils near the top will scarcely be moving at all. If one were to grasp the spring, say, 30 centimeters above the mass and continue to move that point on the spring just as it moved when the mass was in free oscillation, the motion of the mass would be unaffected. Having done this, one could cut off the top of the spring and be left with a mass on a 30-centimeter long spring that would behave in all ways as if it were on a spring one kilometer long. The JILA scientists use an electronic servo system to produce such a virtual point of suspension.

In the Faller-Rinker system, two side springs (see Figure 1) support a moveable bracket from which the mass-supporting spring (of approximately 30 centimeter length) is hung. The output from a light-emitting diode is focused through a sphere near the bottom of the spring onto a split photodiode in order to sense displacements of the spring. The output from the two halves of the photodiode is amplified and differenced, producing an analog signal that is proportional to the displacement of the mass with respect to this bracket. This signal, processed by a servo-compensating amplifier, drives a loudspeaker voice coil, which in turn supplies the needed force on the bracket to cause it to (nearly) track the motion of the bottom weight. Because the top of the spring is attached to the bracket, the top moves nearly the same amount as the bottom. (The precise degree of tracking is determined by the gain setting of the servo system; thus by changing the gain, the effective length of the spring and the period can be varied.) Note that once the various internal modes of the spring have damped out, the

turn page

spring is essentially stationary in inertial space. As a result, only the fundamental mode remains excitable.

Were an effective spring length equal to half the earth's radius achieved, the change in force on the mass from a small displacement due to the additional stretch of the spring would just be cancelled by the added gravitational pull due to the earth's gravity gradient. As a result, the period in this case would be infinite. To date, the longest effective length the JILA scientists have achieved is 22 kilometers, which resulted in a period of 300 seconds. Accordingly, the mass on the end of this spring (or some arbitrarily large table locked to this mass as an inertial reference, driven for example, by piezoelectric transducers) would provide mechanical isolation from all disturbances higher in frequency than 0.003 Hz.

A practical limit on the achievable equivalent length comes in through the temperature dependence of Young's modulus which typically is on the order of a few parts in 10^3 for familiar spring materials such as steel, beryllium-copper, and fused silica. For example, a spring one kilometer in length made of one of these materials would change its length by an embarrassing 100 centimeters for a temperature change of 1 °C. To get around this "dynamic range" difficulty, the JILA scientists both control the temperature of the device and utilize a special spring material (Ni-Span-C alloy 904) whose Young's modulus temperature coefficient can be as low as a few parts in 10^6. Two sources of drift, and therefore noise, are temperature-associated effects and aging which change the sensitivity of the light source (LED) and position detector. To counteract this type of drift, a servo system is used to keep the long-term summed output of the two halves of the split photocell detector constant in time.

The JILA scientists are specifically developing the "super spring" for use with a portable absolute gravimeter which is presently under development. However, they see a much wider application of the spring as the heart of a broad class of highly effective devices for the mechanical isolation of scientific instruments.

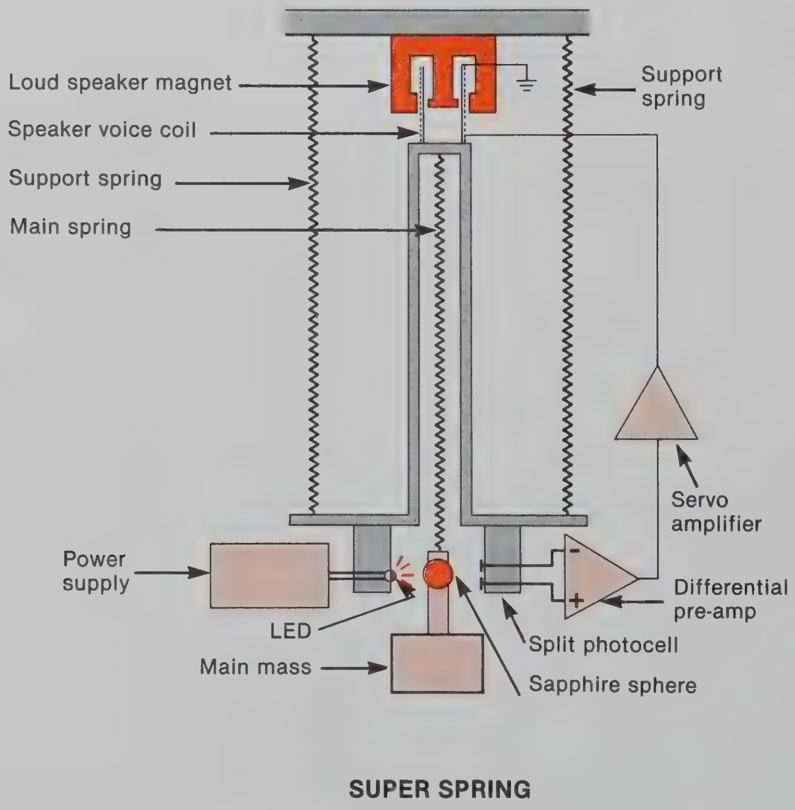


Figure 1—*Schematic diagram of the Faller-Rinker super spring.*

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CONFERENCES

For general information on NBS conferences, contact JoAnn Lorden, NBS Public Information Division, Washington, D.C. 20234, 301/921-2721.

COAL-BASED ENERGY TECHNIQUES CONFERENCE

Materials research in energy technology—specifically as it relates to the use of coal as an energy source—will be the subject of a 3-day conference to be held October 9-11, 1979, at the National Bureau of Standards, Gaithersburg, Md.

The Fourth Annual Conference on Materials for Coal Conversion and Utilization is sponsored by NBS, the Electric Power Research Institute, the U.S. Department of Energy, and the Gas Research Institute.

Using coal more efficiently, and in an environmentally acceptable way, depends on the development and commercialization of several promising conversion systems. Materials problems, however, limit rapid implementation of these new and improved systems. The purpose of this conference is to provide a forum for the discussion of potential solutions to these problems by engineers and scientists from private industry, universities, and government laboratories.

The conference will feature a general session in which authorities in the field will discuss their views on materials design requirements for the coal conversion, coal utilization, magnetohydrodynamics (MHD), and emerging structural ceramics areas. In addition, there will be four technical sessions on:

—Metals for coal conversion, high temperature applications: corrosion, sulfidation, physical properties, and alloy development.

—Metals for coal conversion, low temperature applications: corrosion in liquefaction processes, fracture mechanics of pressure vessel steels, and alloy development.

—Ceramics and refractories for coal gasification, MHD, and structural applications.

—Materials for direct utilization of coal: heat exchanger and turbine materials.

Keynote speakers will lead off each technical session; they will be followed by a panel discussion by well known investigators in the field, who will also highlight their own areas of research. Questions and comments from the audience will be encouraged to make the conference as informative and useful as possible.

For further information contact: Kathy Stang, B348 Materials Building, NBS, 301/921-3295.

BUILDING REHABILITATION CONFERENCE

A building rehabilitation conference will be held December 10-11, 1979, in San Francisco, California. This meeting is sponsored jointly by the National Bureau of Standards and the National Conference of States on Building Codes and Standards.

Building researchers, builders, and state and local regulatory officials as well as architects and engineers are expected to participate in the meeting. The following topics will be discussed:

—Building code development and enforcement

—Research and technology

—Seismic considerations

—Legal implications

—Economic approaches

—Energy conservation

For further information, contact Sandra Berry, Building Economics and Regulatory Technology Division, Center for Building Technology, B226 Building Research Building, NBS, Washington, D.C. 20234, 301/921-2689.

SIXTH TEMPERATURE SYMPOSIUM

Ideas and suggestions are being solicited for a planned Sixth Symposium on Temperature—Its Measurement and Control in Science and Industry, which will be held in Washington, D.C., from March 14 to 18, 1982.

As in previous years, the Symposium will be cosponsored by the American Institute of Physics (AIP), the Instrument Society of America (ISA), and the National Bureau of Standards.

This will be only the sixth meeting of the Temperature Symposium since its inception in 1919. Topics and papers are expected to include the fundamentals of thermometry as they apply to the definition of the International Practical Temperature Scale (IPTS), since the research foundation for a revised IPTS is now in preparation in many laboratories. In a departure from the format of recent Symposia, the Sixth will include exhibits of new devices for temperature measurement instrumentation and control. The feasibility of workshop sessions on various aspects of these topics is also under consideration.

The General Committee Symposium is being chaired by L. G. Rubin of the National Magnet Laboratory of the Massachusetts Institute of Technology. Other members of the committee include Dr. Chun H. Cho of Fisher Controls Co. (ISA); C. Douglas Hetrick of the Instrument Society of America; Dr. Ralph P. Hudson of the National Bureau of Standards; Dr. James F. Schooley, also of NBS, who chairs the Symposium Program Committee; Robert H. Marks and Dr. A. W. K. Metzner of the American Institute of Physics; and two members-at-large, Dr. H. Preston-Thomas of the Canadian National Research Council, who chairs the Consultative Committee on Thermometry of the International Committee for Weights and Measures, and Edward D. Zysk of Engelhard Industries, who chairs the ASTM Committee E20 on Temperature Measurement.

The General Committee invites suggestions from thermometrists both in the U.S. and abroad regarding topics and sessions which appear to be appropriate for inclusion in the Symposium.

Comments may be addressed to Dr. James Schooley, Chief, Temperature Measurements and Standards Division, B128 Physics Building, NBS, Washington, D.C. 20234.

A list of the names and addresses of the members of the General Committee of the Sixth Symposium on Temperature is included for your information.

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CONFERENCE CALENDAR

September 5-7
SYMPOSIUM ON EDDY CURRENT NONDESTRUCTIVE TESTING, NBS, Gaithersburg, MD; sponsored by NBS, ASTM, and ASNT; contact: George Birnbaum, A363 Materials Building, 301/921-3331.

September 11
4TH ANNUAL NBS-NCSBCS JOINT CONFERENCE ON RESEARCH AND INNOVATION IN THE BUILDING REGULATORY PROCESS; Chase Park Plaza, St. Louis, Missouri; sponsored by NBS; contact: Sandra Berry, B226 Technology Building, 301/921-2689.

September 18-21
IMPACT OF IMPROVED CLOCKS AND OSCILLATORS ON COMMUNICATION AND NAVIGATION SYSTEMS WORKSHOP; Gaithersburg, MD; sponsored by the Air Force Office of Scientific Research with the Cooperation of NBS; contact: S. Stein, NBS, Boulder, 303/499-1000, ext. 3277.

September 25-26
NATIONAL CONFERENCE ON LABORATORY EVALUATION; NBS, Gaithersburg, MD; sponsored by NBS; contact: G. Berman, 301/921-2427.

October 9-11
FOURTH ANNUAL CONFERENCE ON MATERIALS FOR COAL CONVERSION AND UTILIZATION, NBS, Gaithersburg, MD; sponsored by NBS and DOE; contact: Samuel Schneider, B308 Materials Building, 301/921-2893.

***October 15-17**
NATIONAL CONFERENCE OF STANDARDS LABORATORIES, Hilton Harvest House Hotel, Boulder, CO; sponsored by NBS, NCSL; contact: K. Armstrong, 303/499-1000, ext. 3787.

October 23-26
JOINT CONFERENCE ON MEASUREMENT AND STANDARDS FOR RECYCLED OIL/SYSTEMS PERFORMANCE AND DURABILITY, NBS, Gaithersburg, MD; sponsored by NBS, MFPG, ASTM Technical Division P on Recycled Petroleum Products and Lubricants; contact: Donald Becker, B50 Physics Building, 301/921-2621, or Harry Burnett, B265 Materials Building, 301/921-2812.

***October 31-November 2**
MEDILOG' 79, NBS, Gaithersburg, MD; sponsored by NBS and DOD; contact: Charles Hulick, A740 Administration Building, 301/921-3465.

December 3-5
1979 WINTER SIMULATION CONFERENCE, San Diego, California; sponsored by NBS, AIIE, ACM, IEEE, ORSA, TIMS, and SCS; contact: Paul Roth, B250 Technology Building, 301/921-3545.

***December 10-11**
RESEARCH OPPORTUNITIES IN RESOURCE DISCOVERY, NBS, Gaithersburg; MD; sponsored by NBS, DOE, NSF, National Center for Resource Discovery; contact: Joseph Berke, B326 Physics Building, 301/921-2343.

***December 12**
COMPUTER NETWORKING SYMPOSIUM NBS, Gaithersburg, MD, sponsored by NBS and IEEE; contact: Fran Nielsen, B212 Technology Building, 301/921-2601.

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* New Listings

PUBLICATIONS

NEW SRM CATALOG

*National Bureau of Standards Special Publication 260, Supersedes NBS Spec. Publ. 260-1975-76 Edition, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-1979-80 catalog, 107 pages (Apr. 1979) Stock No. 003-003-02048-6, $3.**

Over 1000 different materials are described in the new 1979-80 National Bureau of Standards' Standard Reference Materials catalog. The catalog lists new materials, available materials, materials in preparation, and materials to be discontinued.

Most of the materials in the catalog are Standard Reference Materials (SRM's), which are well characterized, homogeneous, stable materials or artifacts with specific properties or components measured and certified by NBS. In fiscal year 1978 alone, NBS distributed 37 000 SRM's to more than 10 000 users.

SRM's are used in a variety of measurement and research applications in industrial, environmental, and clinical laboratories. SRM's are prepared to help in the development of accurate methods of analysis; to calibrate measurements systems used to facilitate the exchange of goods, institute quality control, determine performance characteristics, or measure some property at the limit of the state-of-the-art; and to ensure the long-term adequacy and integrity of quality control processes. In these ways, SRM's help assure the compatibility and accuracy of measurements in many areas—from science and technology to trade and commerce.

Also listed in the catalog are Research Materials and Special Reference Materials. Research Materials are not certified, rather they are issued with a "Report of Investigation" for which the NBS staff member who authored the report is the sole authority. A Research Material is intended primarily to further scientific or technical research on that particular material.

Special Reference Materials are reference materials produced and certified or guaranteed by other government agencies, standards bodies, or other nonprofit organizations, and distributed by NBS.

"TIP THE SCALE" TOWARD HISTORIC PRESERVATION

Weber, S. F., Historic Preservation Incentives of the 1976 Tax Reform Act: An Economic Analysis, Nat. Bur. Stand. (U.S.), Tech. Note 980, 32 pages (Feb. 1979) Stock No. 003-003-02015-0, $1.50.

Rehabilitation of historic buildings has been made significantly more attractive by revisions in Federal tax law, according to an economic analysis conducted by the National Bureau of Standards.

The NBS study finds that changes in the statute dealing with income-producing historic buildings have effectively reversed the tax bias which formerly favored demolition and redevelopment over restoration and rehabilitation.

In addition to providing policy makers with information on the effectiveness of these tax incentives for historic preservation, the report should help corporate investors make cost-effective decisions regarding preservation of historic, nonresidential buildings. With minor adjustments, the approach developed in this report could also be applied to incentives for other categories of building rehabilitation.

By allowing more rapid acceleration of depreciation schedules for new buildings and permitting demolition costs to be deducted in the year in which they occur, U.S. tax laws traditionally tended to penalize historic preservation projects. The Tax Reform Act (TRA) of 1976 includes certain provisions designed to create a more favorable tax environment by removing those tax penalties.

The NBS analysis by Dr. Stephen F. Weber in the Bureau's Center for Building Technology was conducted from a life-cycle cost point of view so that all of the financial impacts of the tax provisions occurring over the lifetime of the structure could be taken into account. Thus, full consideration is given to the tax benefits occurring each year, as well as to the tax liabilities occurring when the property is sold.

The results of the Bureau's analysis indicate that the "TRA" has significantly affected the economic trade-off between rehabilitation and redevelopment for historic properties." According to the study, rehabilitation undertaken before the TRA was enacted had been between four and nine percent more costly than redevelopment. Since enactment of the TRA, the rapid amortization provision has caused rehabilitation to be between 13 and 28 percent less costly than redevelopment. The accelerated depreciation provision for substantial rehabilitation has also made rehabilitation comparatively less costly.

Weber, author of the report, says that "The TRA provisions appear to have tipped the tax scale in favor of historic preservation, just what they were designed to do." He adds, "This analysis

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** Publications cited here may be purchased at the listed price from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (foreign: add 25%). Microfiche copies are available from the National Technical Information Service, Springfield, VA 22161. For more complete periodic listings of all scientific papers and articles produced by NBS staff, write: Editor, Publications Newsletter, Administration Building, National Bureau of Standards, Washington, D.C. 20234.*

OF THE NATIONAL BUREAU OF STANDARDS

suggests that current and prospective owners of historic structures now have a strong incentive to consider rehabilitation instead of demolition."

Computer Science and Technology

Mohr, J. M., Agrawala, A. K., and Flannagan, J. F., Computer Science and Technology: A Guide to Major Job Accounting Systems: The Logger System of the UNIVAC 1100 Series Operating System, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-43, 79 pages (Dec. 1978) Stock No. 003-003-02003-6, $2.50.

Nutt, G. J., Computer Science and Technology: A Survey of Remote Monitoring, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-42, 34 pages (Jan. 1979) Stock No. 003-003-02013-3, $1.50.

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Health and Safety

Berger, R. E., System for Assessing Eye Injury Potential of Propelled Objects, J. Res. Nat. Bur. Stand. (U.S.), *84,* No 1, 9-19 (Jan-Feb. 1979).

Chapman, R. E., and Kowalski, J. G., Guidelines for Cost-Effective Lead Paint Abatement, Nat. Bur. Stand. (U.S.), Tech. Note 971, 88 pages (Jan. 1979) Stock No. 003-003-02014-1, $2.75.

Fechter, J. V. and Robertson, E. M., Catalog of Security Equipment, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-35, 58 pages (Nov. 1978) Stock No. 003-003-01970-4, $2.30.

Electronic Technology

Leedy, T. F., and Liu, Y. M., Semiconductor Measurement Technology: Microelectronic Processsing Laboratory at NBS, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-53, 33 pages (Dec. 1978) Stock No. 003-003-02004-4, $1.50.

Energy Conservation and Production

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Environmental Studies: Pollution Measurement

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Wendt, J., Kowalski, J., Bass, A. M., Ellis, C., and Patapoff, M., Interagency Comparison of Ultraviolet Photometric Standards for Measuring Ozone Concentrations, Nat. Bur. Stand. (U.S.), Spec. Publ. 529, 25 pages (Dec. 1978) Stock No. 003-003-02002-8, $1.30.

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Purtell, L. P., and Klebanoff, P. S., A Low-Velocity Airflow Calibration and Research Facility, Nat. Bur. Stand. (U.S.), Tech. Note 989, 21 pages (Mar. 1979) Stock No. 003-003-02038-9, $1.20.

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Yolken, H. T., and Bullard, J. E., Eds. Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Materials. Proceedings from American Nuclear Society Topical Meeting held in Williamsburg, VA, May 15-17, 1978, Nat. Bur. Stand. (U.S.), Spec. Publ. 528, 304 pages (Nov. 1978) Stock No. 003-003-01996-8, $4.75.

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Pierman, B. C., Ed., Color in the Health Care Environment. Proceedings of a Special Workshop held at the National Bureau of Standards, Gaithersburg, MD, Nov. 16, 1976, Nat. Bur. Stand. (U.S.), Spec. Publ. 516, 35 pages (Sept. 1978) Stock No. 003-003-01957-7, $1.60.

NEWS BRIEFS

FIRE SAFETY AND THE DEVELOPMENTALLY DISABLED. The behavioral and physical characteristics of developmentally disabled individuals residing in community-based group homes similar to boarding houses and halfway homes are being explored by the Bureau's Center for Fire Research. NBS is interested in the subject as part of a joint fire safety program with the Department of Health, Education and Welfare. A baseline of information on the developmentally disabled and their particular handicaps has been drawn up by researchers at the University of Wisconsin-Madison under contract to the Bureau. This work will help in planning realistic fire safety requirements in group homes.

STANDARDS LABORATORIES CONFERENCE. Challenges for the Professional Metrology Manager of the Eighties will be the theme of the 18th annual workshop and symposium of the National Conference of Standards Laboratories on October 15-17, 1979 in Boulder, Colo. Participants at the 3-day meeting will address the changing needs of modern metrology in areas such as laboratory personnel; radiation standards; measurement assurance programs; traceability; introduction to optical fiber standards; and preparing management for metrology's role in the future.

INFORMATION EXCHANGE ON SOFTWARE TOOLS TESTING. As part of its program to develop standards that will improve Federal computer software quality, NBS is coordinating an information exchange on testing and development aids. Developers and users of software tools are invited to participate in the exchange through: Tools Project, NBS Institute for Computer Sciences and Technology, A265 Technology Building, Wash., D.C. 20234.

OPTICAL MATERIALS FOR LASERS. The proceedings of the 10th Symposium on Optical Materials for High Power Lasers (September 1978) have been published as NBS Special Publication 541, titled Laser Induced Damage in Optical Materials: 1978. This well-known meeting attracted specialists from all over the world to discuss new developments in laser materials. The proceedings also contain comprehensive papers reviewing the state-of-the-art. Paperpack, 362 pages, order from U.S. GPO, Wash., D.C. 20402, SD Stock No. 003-003-02052-4, $5.50.

COMPUTER MEMORY FORECAST. Analyses of the technology of computer peripheral memory systems and forecast of future uses are presented in Computer Peripheral Memory System Forecast, a new report from NBS. The report compares both existing and developing memory systems for cost and performance characteristics. An extensive bibliography of related documents is included. This NBS Special Publication 500-45 is a paperback, 147 pages, available from the U.S. GPO, Wash., D.C. 20402, SD Stock No. 003-003-02039-7, $3.25.

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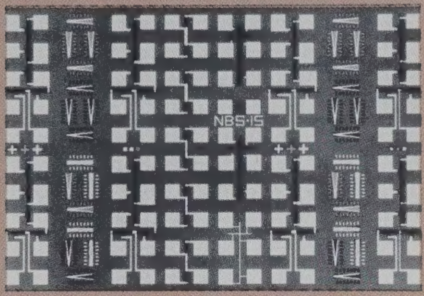

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